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ELECTRONICS ENGINEERING

OF CANADA

Radiobeacon means safer navigation

Microwave power measurement made easy

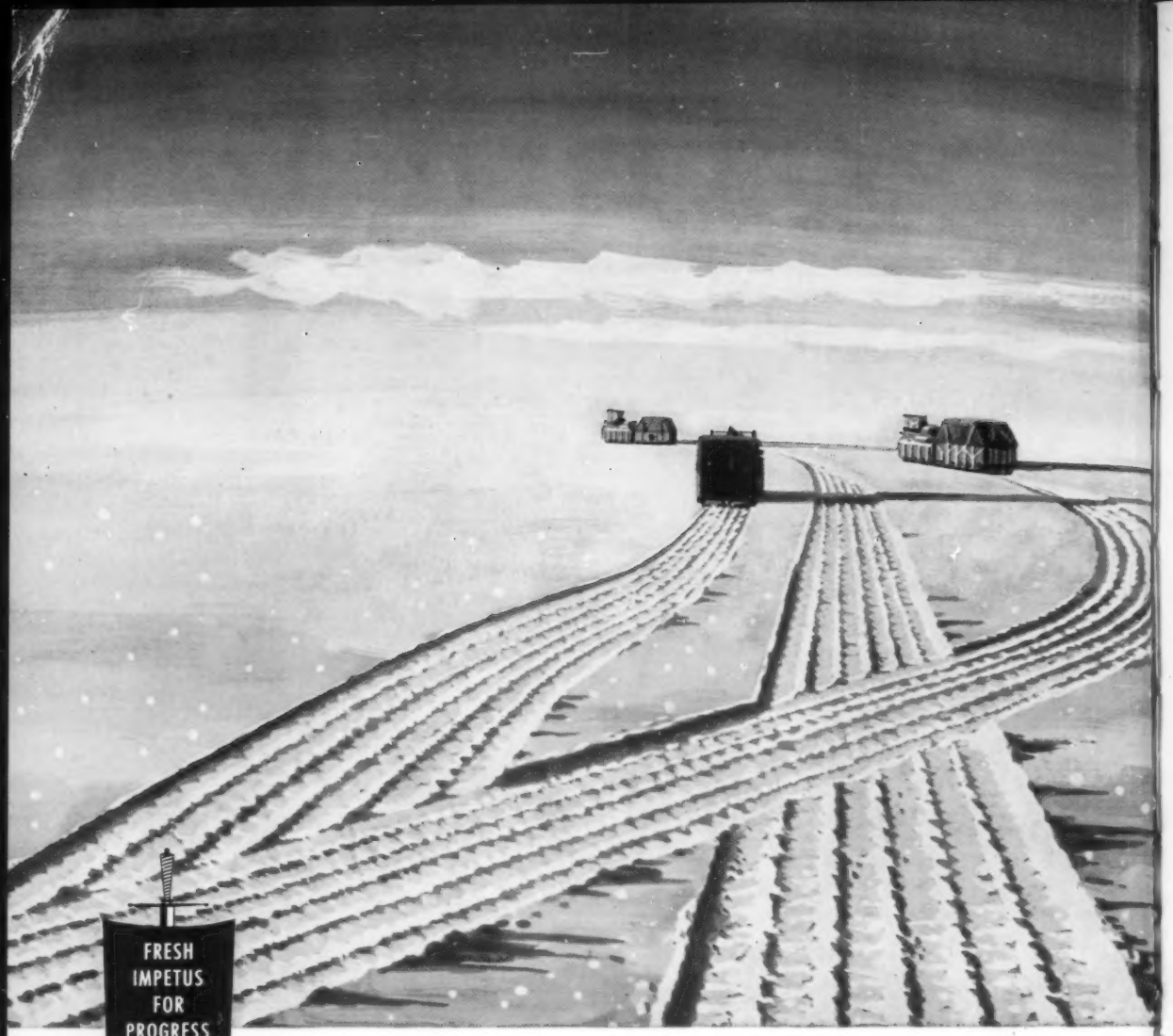
How to design regulated supplies

Transistors take over

Crystal production is a skilled job

Unit will analyze chart records

index page one



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What we have learned *in the air*—we apply *on the ground.* See these snowmobile-type vehicles: they are a solution to an unique problem of transport over trackless terrain through snow, muskeg, sand or water, and were Canadair-developed and manufactured for the Canadian Armed Forces.

And Canadair's research and development division is ready to undertake other special jobs in many fields, such as: research, development problems, custom designs, electronics, digital and analogue electronic computing, structural and mechanical testing: in all a service designed to offer fresh impetus for progress.

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• Guided Missiles • Nuclear Engineering

CA57-CANT-1

june 1957

volume one, number 2

ELECTRONICS ENGINEERING

OF CANADA

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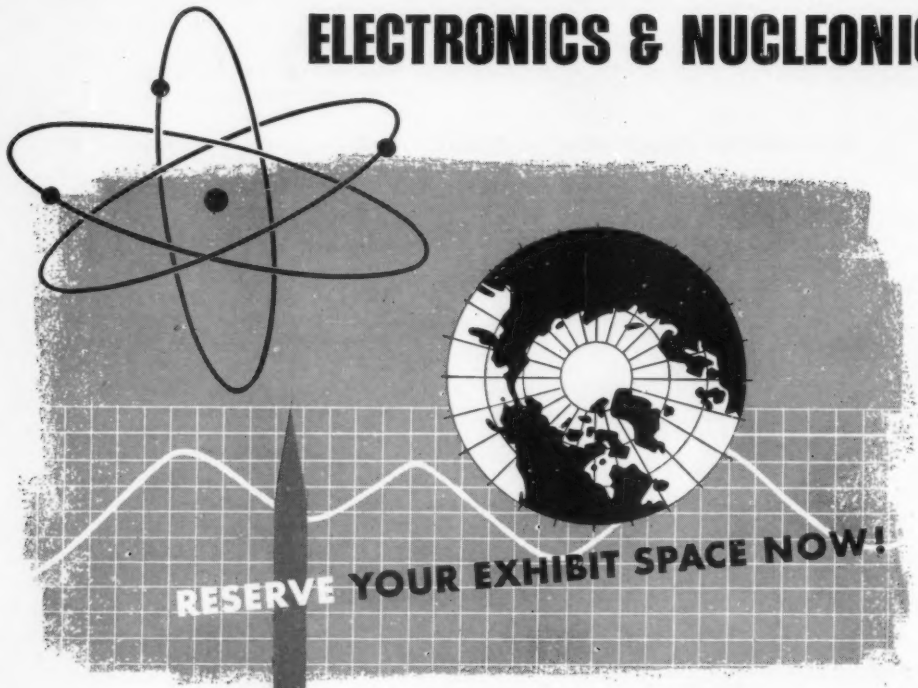
***our cover design** *Magnetic amplifiers are symbolized by the familiar hysterisis loop on the left flowing into the windings of a toroidal reactor. Based on experimental photographs by John Sebert.*

Announcing the second annual:

IRE CANADIAN CONVENTION

AND EXPOSITION *Automotive Building, Exhibition Park, Toronto, Canada, October 16, 17, 18, 1957*

ELECTRONICS & NUCLEONICS



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Dalton and Biringer

Joint author of "Magnetic amplifiers—latest trends," **Paul P. Biringer,** P.Eng., comes from Hungary. After graduating in Budapest he continued his studies in Stockholm and at the University of Toronto, obtaining a Ph.D. in electrical engineering. At present he is a research associate at the U of T, consultant to the Massachusetts Institute of Technology, Boston, and various engineering companies on magnetic amplifiers and magnetic frequency multipliers. He is a permanent member of Cigre, Paris, a member of the Swedish Engineering Association and serves on the magnetic amplifier committee of the AIEE.

Ian R. Dalton, P.Eng., graduated from the U of T in electrical engineering in 1950, taking his Master of Science degree at Northwestern a year later and majoring in control systems. After a year's research at Manchester University, England, he came back to the U of T where he is now a lecturer in the Electrical Engineering Department.

W. M. Cameron

After spending the first 18 months of World War II on the North Atlantic (Transponder radiobeacon) came ashore in 1941 as an instructor in electronics at the Radio School in Saint John, N.B. After designing a radar system he was invited to join the National Research Council and has been there ever since.

Of his earlier life, he says, he studied radio and survived the depression selling and fixing radios, obtaining a radio operator's licence in the process.

He is an amateur astronomer, member of the Royal Astronomical Society of Canada and a member of the Observer Corps.

Beginning as a junior wireless operator (he is one of the fastest telegraphers in the world) **Samuel Freedman,** who writes on "Calorimeter makes microwave power measurement easy" now heads his own company in Santee, California.

His main interest is in microwave work but he has done a lot of research on electronic uses for metallurgy including shell molding of aluminum waveguides and special purpose metals for fluxless and corrosionless soldering and welding. Recently he put some of his metal, powdered, in the ground and reports that it improves germination by 50% and gives faster and bigger growth to plants.

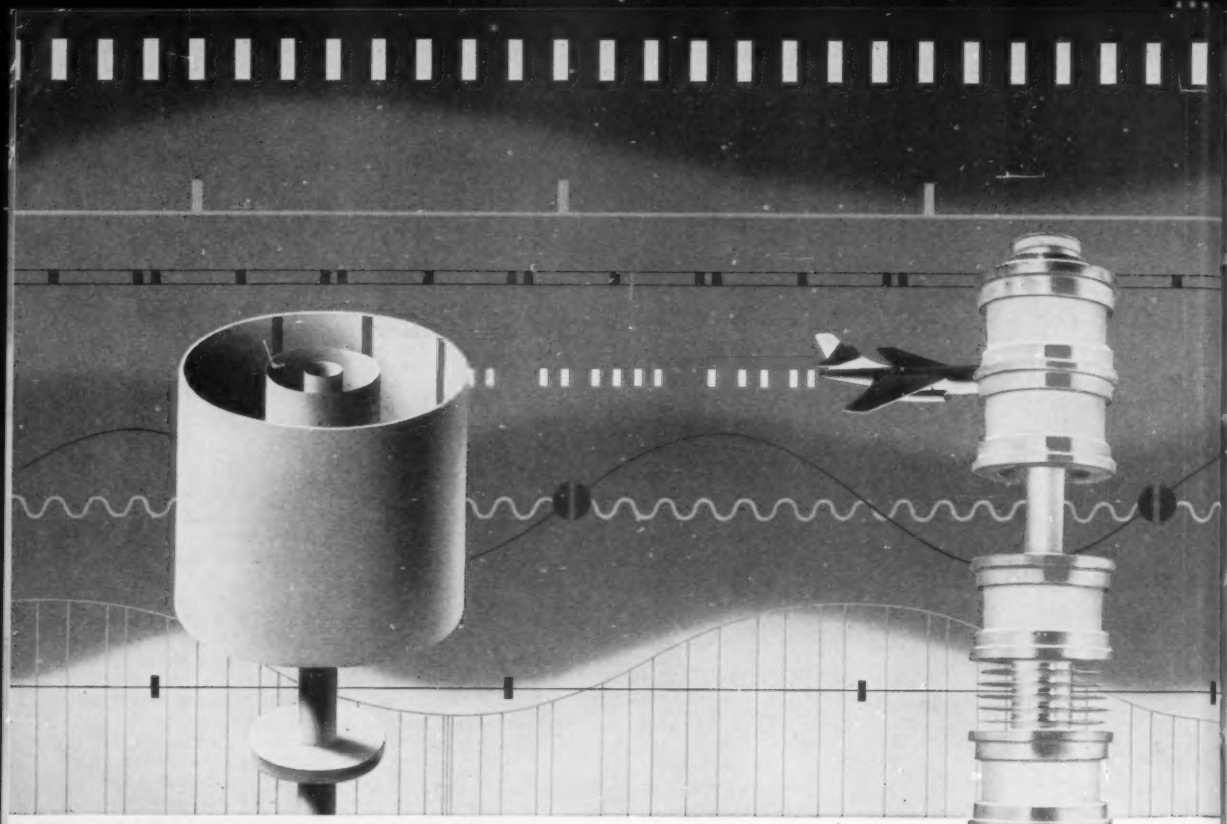
He lectures widely and writes fast. A note on his article said: "I felt like writing tonight, so here it is." That was two days after he had been asked to do it.

During most of his six years at the University of Copenhagen, Danish-born **Preben Gomard,** P.Eng. (How to design regulated power supplies) was serving in the Resistance Movement against the Nazis. In 1946 he graduated MSc. in radio engineering and after working in Copenhagen came to Canada in 1949 where he joined Ryerson Institute in Toronto as an instructor.

From 1950 to 1953 he was with Canadian Westinghouse in Hamilton in the communication engineering section. Then he moved to T. S. Farley Ltd. and was mainly concerned with deflection components and circuitry from television. He has recently joined the Canadian Electronics Company who are also in Hamilton.

a Maclean-Hunter publication

Authorized as second class mail, Post Office Department, Ottawa.
Printed and published by Maclean-Hunter Publishing Company Limited. Editorial and Advertising Offices: 212 King Street West, Toronto 2, Canada. Address all correspondence: P.O. Box 100, Toronto, Canada.
Horace T. Hunter, Chairman of the Board; Floyd S. Chalmers, President; Donald F. Hunter, Vice-President and Managing Director; Thomas H. Howse, Vice-President and Comptroller.
Publishers of National Magazines in Canada; Maclean's, Chatelaine, Canadian Homes and Gardens, Business newspapers in Canada: Canadian Hotel Review; Fountains in Canada; Heating and Plumbing Engineer; Bus and Truck Transport; Canadian Advertising; Canadian Automotive Trade; Canadian Aviation; Canadian Grocer; Canadian Machinery; Canadian Packaging; Canadian Paint and Varnish; Canadian Printer and Publisher; Canadian Shipping; Canadian Stationer; Civic Administration; Drug Merchandising; Electronics Engineering of Canada; L'Epicier; The Financial Post; Hardware and Metal; Marketing; Men's Wear; Modern Power; Painting and Decorating Contractor; Plant Administration; Le Quincaillier; Electrical Contractor; Style; Office Equipment & Methods; Home Goods Retailing; Photo Trade; Building Supply Dealer; Business newspapers in U. S. and U. K.; Inland Printer, Book Products, Concrete Products, British Printer.
OTHER SERVICES: The Financial Post Corporation Service; Canadian Press Clipping Service; Commercial Printing Division.
Offices at 1242 Peel Street, Montreal; Maclean-Hunter Limited, 125 Strand, London (Eng.).
Subscription rates: Canada $5.00 per year, two years $9.00, three years $13.00. Single copy price, $1.00. Other countries $8.00 per year.



Eimac X676 Modulating Anode Klystron

Shaped RF Pulse, 30 KW Peak Power Output for 955-1220 mc Air Navigation Systems

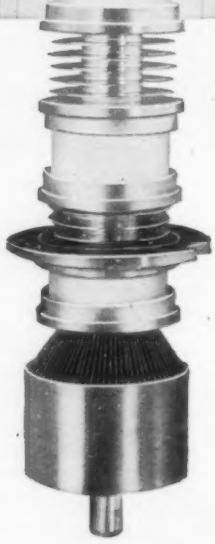
Designed for air navigation systems, the Eimac X676 three cavity, air cooled klystron will deliver 30 KW peak power output in the 955 to 1220 mc range. With a power gain of 35 db, this tube has an efficiency of 40 per cent.

A typical air navigation systems requirement is a shaped RF pulse output to eliminate spectrum interference in adjacent channels. The Eimac X676 klystron is ideally suited to this service. The modulating anode permits pulsing the beam current while keeping the accelerating voltage constant. Also, the modulator circuit for this application is quite simple.

The RF cavities are external to the vacuum system and detachable from the klystron. The user may purchase spare tubes without buying additional tuning and focusing assemblies.

For the design engineer, the features of the X676 simplify circuitry—for the equipment operators the X676 provides reliable, long-lived performance at moderate cost.

For further information about the Eimac X676 Modulating Anode Klystron, consult our Application Engineering Department. Also available are two highly informative booklets; "The Care and Feeding of Klystrons" and "Klystron Facts . . . Case Four."



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Typical Pulse Operation X676

DC Beam Voltage . . . . . 24 KV	Power Output . . . . . 32 KW	Power Gain . . . . . 35 db
DC Beam Current . . . . . 3.3 Amps	Driving Power . . . . . 10 watts	Average Power . . . . . 1 KW
Power Input . . . . . 80 KW	Efficiency 40%	

Five new posts are named by RCA Victor

Marconi's production chief
Expansion by Philips
TV moves in Quebec
To direct CAE research
Navigation expert at CDC

Five new appointments have been made by RCA Victor in their new Engineering Products Department. J. G. Sutherland, a graduate from the University of Manitoba, is now manager, Engineering Products Commercial Marketing Department. He has been with RCA Victor since 1946 and during the war served in the Royal Canadian Signal Corps.

H. B. Seabrook has moved to his native Vancouver as manager of the

Sutherland

Seabrook

Vancouver district office, Engineering Products Commercial Marketing. Mr. Seabrooke, who joined the Company in 1942, has had broad experience in all aspects of broadcasting.

Charles Boisvert has been named manager of the Montreal District office in the same department. A graduate in engineering from McGill University, he was engaged in radio research and development for the Department of Defence before joining RCA Victor in 1953.

The other two appointments are: Andre Gilbert, Sales Engineer for the Montreal District office and Geoffry M. Kennedy as Sales Engineer, Land Mobile Marketing. Both are graduates of McGill University.

Production head of Canadian Marconi

Thomas Marshall has moved from production manager of Canadián Marconi's Broadcast and Television Receiver Division to Manager, Production Department.

He is in charge of all divisional production phases, including purchasing, estimating, warehousing and shipping, electrical assembly, primary parts, special products and plant maintenance.

Canadian Marconi also announce the appointment of L. T. Bird as United Kingdom representative. He has been associated with the company for 27 years.

To direct product design group

PSC Applied Research have made Roy L. Adams Chief Product Engineer. He joined PSC Applied Research in 1955 and has served as assistant production manager, Electrical and Electronic Components, since 1956.

Prototype models of equipment will be produced by his group and complete drawings, parts schedules and assembly procedure will be prepared before the product enters into the final production stage.

E. D. Rushbrook has been made secretary-treasurer of the company.

Manager for expanded market program

Emmanuel Batler, B.Sc. has become manager, Professional Products Division, of Philips Industries Ltd. He will direct the expanded marketing program of the Philips Scientific, Industrial and Medical Apparatus Divisions.

Mr. Batler was formerly general manager of Cushing and Nevell Ltd. and has had experience in technical and business areas in both the United States and Canada. He settled in Canada in 1952.

Quebec now has two private stations

With the inauguration of new station CKMI-TV, Quebec City became the first major metropolitan market in Canada with two competitive, privately owned television operations. CKMI-TV puts out programs in English and the other station, CFCM-TV in French.

Jean A. Pouliot, former executive engineer, Famous Players (Canadian) Corporation Limited, is general manager of Television de Quebec (Canada) Ltd. with administrative responsibility for both stations, CFCM-TV and CKMI-TV.

Arthur P. Fitzgibbons becomes director of operations, CKMI-TV. He was formerly commercial manager of CFCM-TV.

Cooke

Konzuk

Two new posts for CAE expansion

Two new positions have been created by Canadian Aviation Electronics to support the company's expansion in the military and commercial electronics field.

R. W. Cooke is made vice-president, Engineering Products. He will direct CAE's research and development program and assume policy responsibility for engineering products activities. Mr. Cooke is a graduate of the University of Western Ontario in physics and mathematics.

The second appointment is of C. J. Konzuk as general manager, Eastern Division. Mr. Konzuk, a graduate of McGill University in electrical engineering and a wartime radar officer in Canada and overseas, has been with CAE since 1951, lately as manager of the operations division in Montreal.

Navigation specialist for CDC division

Former Naval expert, Lt/Cdr. A. J. McCulloch RN (ret) is now with Computing Devices of Canada and is responsible for the sale of the Decca Navigator to marine users in Canada.

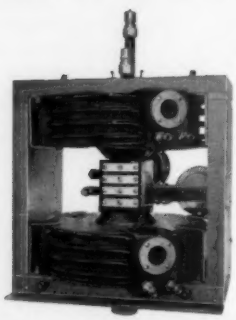
Cdr. McCulloch joined the Royal Navy in 1928 as a boy seaman. Since then his duties have almost continuously involved him in air and surface navigation and communications. In 1934 he took up naval aviation as a specialist.

He has been in Canada since 1952 on loan to the RCN to establish Canada's first naval air navigation school at Shearwater, Nova Scotia.

(See page 49)

ANOTHER VARIAN FIRST!

2 kW SHF Varian Klystron



The VA-804D (4.85—5.0 kMc) mounted in its focusing magnet, the VA-1504.

A vital component of the new Canadian Westinghouse SHF scatter transmitter, now being operated in a "proving ground" circuit between Hamilton and Kinmount, Ontario, is the Varian VA-804 klystron amplifier, designed specifically for forward scatter communication service. The now familiar qualities of all Varian klystrons – remarkable efficiency (see below), economy, reliability, and proved performance – made this tube the logical choice for Westinghouse.

Electrical Characteristics:

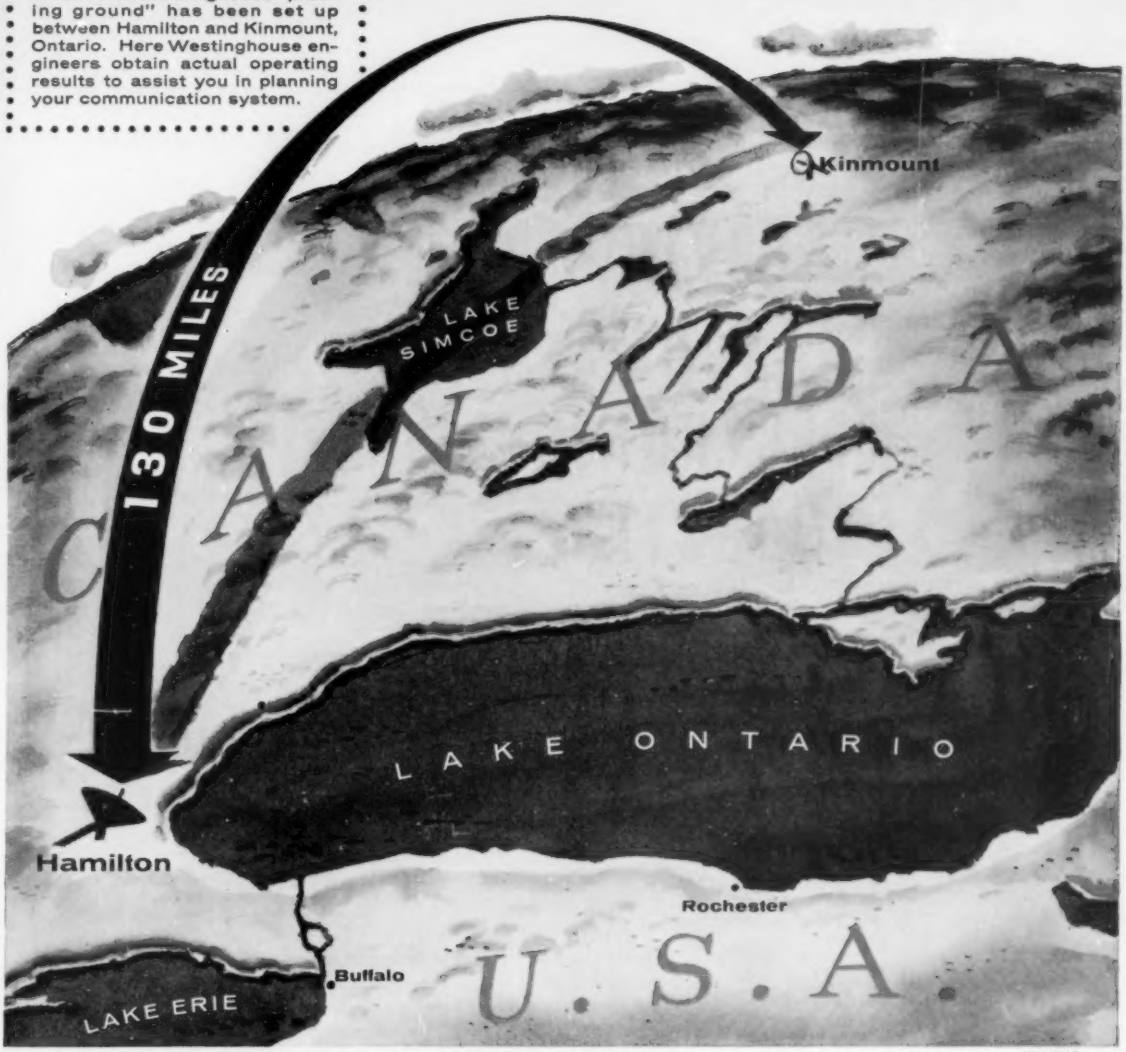
Frequency – 4400 to 5875 Mc
Power – 2 kW minimum
Gain – 50 db
Efficiency – 40% nominal

For a complete description of this and other Varian klystrons contact your local Varian Representative or write Varian Associates, Application Engineering Department.

THE MARK OF LEADERSHIP

VARIAN associates
OF CANADA, LTD.
GEORGETOWN, ONTARIO

A 130-mile Westinghouse "proving ground" has been set up between Hamilton and Kinmount, Ontario. Here Westinghouse engineers obtain actual operating results to assist you in planning your communication system.



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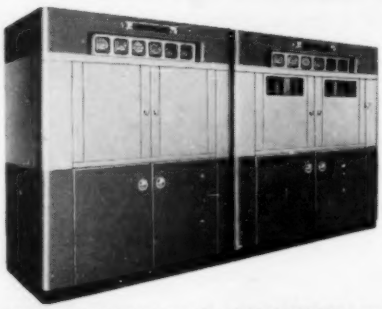
ANOTHER WESTINGHOUSE FIRST!

SHF "Scatter" Transmission



New Westinghouse 4400-5000 mc. Transmitting and Receiving Equipment is compactly and durably designed for truck mounting or fixed installation for either commercial or military application.

● Now for the first time in the communications field, scatter equipment for super-high frequency transmission for fixed or transportable operation has been introduced by Canadian Westinghouse.

The new Westinghouse "Scatter" communications equipment is designed for high quality, high reliability transmission of voice, teletype, telemetering, facsimile, television and data signals over hops of 100 to 200 miles. Voice capacity for multi-channel operation extends to 120-150 channels.

Contact your local Westinghouse Sales Office for Descriptive Bulletin H83-100 or write Canadian Westinghouse Company Limited, Electronics Division, Hamilton, Canada.

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ELECTRONICS ENGINEERING

OF CANADA

This is Canada's newest technical engineering journal for engineers engaged in electronics—in management, design and application. Written and spoken comments from readers of the first issue in May have been most gratifying to our editors, whose plan to make this journal a real source of information to the industry has become a reality.

As you will see from a study of this June issue, it is the editors' intention to continually improve ELECTRONICS ENGINEERING. Each month, this publication will carry staff articles and articles from recognized authorities on all aspects of the electronics industry in Canada.

Results of an independent survey among advertising buyers can be summed up in the following typical comment:

"There is no better way to gauge the value of a publication as a medium for advertising than to evaluate its editorial content."

By this gauge, ELECTRONICS ENGINEERING scores high!

Use the advertising pages of ELECTRONICS ENGINEERING to reach and sell every month the vital and growing electronics industry. Write today for full details on special positions, rates etc.

ELECTRONICS ENGINEERING
OF CANADA

THE MACLEAN-HUNTER PUBLICATION
481 University Avenue, Toronto

Suggestion saves company thousands of dollars

Decca radar at Dorval
Channel 17 doubles power
Electrohome open new plant
Building for Canada Wire
TV tax unfair say RETMA

Following a suggestion by one of their staff the Canadian Marconi Company estimate that they will be able to save ten thousand dollars a year and thousands of clerical hours. Man who made the suggestion was a young French-Canadian, Jean Lafond and for his efforts he received a cheque for $3,000 from Stuart M. Finlayson, president of Canadian Marconi.

The suggestion resulted in a new bill of material system being instituted.

Experts estimate that production of defense and domestic equipment should run more smoothly, schedules are much more likely to be maintained and the possibility of hidden costs should be drastically reduced.

Finlayson and Lafond

The preparation of the suggestion involved approximately one hundred hours of Lafond's leisure time working out the details before presenting his idea in final form. The proposal was investigated by company officials and the suggestions plan committee and the knowledge gained during this research was invaluable when it came to fitting Lafond's idea into the Marconi scheme of things.

Decca airport radar used at Dorval

First of four new airport radar surveillance units to be installed in Canada—type MR75 made by Decca Radar Ltd., is in use at Dorval Airport, Montreal.

Canada's Department of Transport will install similar medium range AASR (Airport and Airway Surveillance Radar) units made by Decca at Toronto, Winnipeg and Vancouver—thus covering this country's four major airports by the new equipment.

Beginning next year the department will establish long-range airway surveillance radar at 15 air centres coast to coast. This equipment, designed by Raytheon Manufacturing Co., Waltham, Mass., is being made in Canada by Dominion Electrohome Industries, Ltd., Kitchener, Ont.

TV station to double power output

The Buffalo TV station, WBUF, channel 17, will double its power output early in August. That will give a total of a million watts which, says Charles C. V. Bevis Jr., general manager of the station, means: "All communities beyond metropolitan Buffalo in our present coverage area are expected to receive a much-improved signal and what is now our outer area will be extended a greater distance. Toronto, Hamilton and Oshawa viewers should benefit greatly."

Of the total television homes in the Ontario peninsula and Toronto about 45,000 — 17% — are equipped to receive channel 17. Estimated retail sales of all-channel sets and converters over the next year should total about $3,900,000 said Mr. Bevis.

New Kitchener plant for Electrohome

Dominion Electrohome, the largest all-Canadian company in its field, has opened a new $650,000 plant on Wellington St. N., Kitchener. The opening was performed by Dr. Sidney E. Smith, president of the University of Toronto.

Dr. Smith said: "Business and universities must link arms. The degree of co-operation will spell success or failure to industrial undertakings in Canada."

Carl A. Pollock, president of the company, announced that Electrohome was already awarding scholarships to universities for Kitchener - Waterloo graduates. Now, to help universities, Electrohome would donate up to $500 a year to the university for each student enrolled on such a scholarship.

Dominion Electrohome, established in 1907, now employs 1,100 people and sales last year totaled a record $13,565,044.

New plant will employ over 100 people

New plant for Canada Wire and Cable Company, now being built at Simcoe, Ontario, will employ over 100 people and will be in production by the end of 1957.

Vice-president and general manager O. W. Titus says "The modern machinery and equipment to be installed will enable the magnet wire division to maintain its production of the widest range of types and sizes of magnet wires in Canada. The plant is a further step in the planned expansion and decentralization of our manufacturing facilities."

Mr. A. V. Armstrong, formerly with Amalgamated Electric Corporation Ltd., has been appointed manager of the magnet wire division of which the Simcoe plant will be the major unit.

Ottawa office for Texas company

A marketing office has been established in Ottawa by Texas instruments Incorporated of Dallas, Texas. Reason, says the company, is "to supply precision electronic devices to the rapidly expanding Canadian electronics market." The office is at 53 Queen St., Ottawa.

Texas Instruments, a 26-year-old electronics and geophysics firm, makes germanium and silicon transistors, silicon rectifiers and diodes, film resistors, precision meters and transformer-type products.

Radio-TV tax unfair say RETMA

The Radio - Electronics - Television Manufacturers Association of Canada has said that the recommendation of the Fowler Royal Commission on Broadcasting to finance the CBC from funds derived from General Revenue was a step in the right direction. However, RETMA was not in favor of the continued imposition of the 15% excise tax to supplement this financing of the CBC, as advocated by the Fowler Report.

RETMA recommended, in its submission to the Royal Commission, that the CBC be financed wholly from General Revenue.

(See page 49)

The facts about Lenkurt's new 4 channel open-wire carrier in a nut shell...*

INTERCONNECTABLE The 45CB is designed to interconnect directly *at carrier frequencies* with 45 class cable and radio carrier. It can completely co-ordinate your entire carrier network—greatly improving service for a minimum outlay.

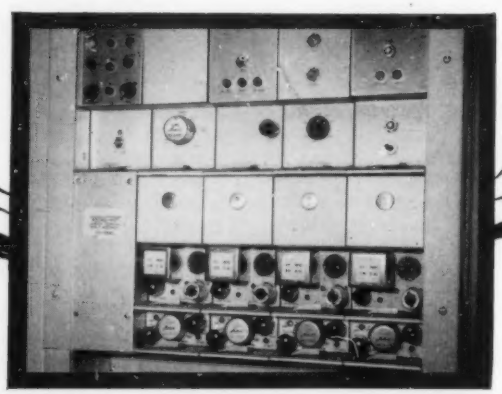
HIGH QUALITY CHANNELS Excellent channel frequency response and stability provide high quality voice channels for short and medium haul toll use.

MINIATURIZED COMPONENTS Maximum amount of equipment in a minimum of space.

PLUG IN CONSTRUCTION More flexible in operation. Fewer parts to stock. Simplified maintenance.

CO-ORDINATES completely with similar carrier systems in the same frequency spectrum. May also be used over low frequency systems to substantially increase circuit capacity.

RELIABILITY Transistorized construction and quality engineering assure unusually high reliability.



** That's the new 45CB system. If you don't know about it already, we'll be delighted to tell you the whole story.*

Write or call Automatic Electric Sales (Canada) Limited, 185 Bartley Drive, Toronto 16, Ontario. Branches in Montreal, Ottawa, Brockville, Hamilton, Winnipeg, Regina, Edmonton, Vancouver.

AUTOMATIC ELECTRIC

ORIGINATORS OF THE DIAL TELEPHONE

5732

What we think

COLOR TV—is the NTSC system good enough?

So far no practical moves have been made to introduce color television into Canada. But it is assumed by everyone, including the Royal Commission on Broadcasting, that Canada will follow the American system. The Fowler report estimates that retransmission of color programs by the CBC should begin in early 1959. But has the NTSC system proved itself? In England they are saying, quite frankly, that it has not. In fact one technical journal heads an editorial on American color television with the words "Color Fiasco."

What are the facts about the American color setup? Firstly, since the introduction in 1955 of the 21-inch compatible color receiver, only 102,000 have been sold. This suggests that the public are not over-enthusiastic. Secondly, picture quality is not as high as it was expected to be, either in color or compatible black and white. This is particularly noticeable in fringe areas.

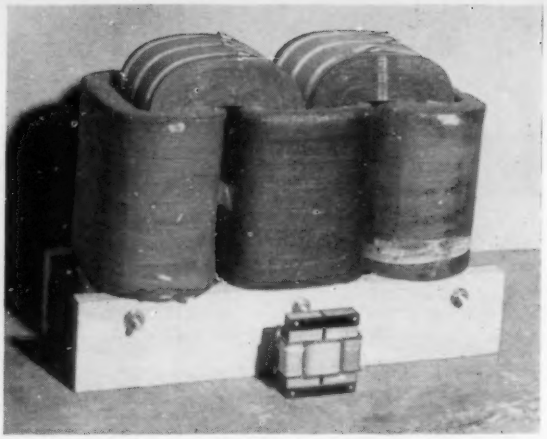
C. O. Stanley, chairman of Pye Ltd., visited the U. S. recently and on his return to England, said that the Americans had made an "over-hasty" decision to get color TV going at all costs.

Now Canada, obviously, could not develop an entirely independent color TV system. It will have to adopt an American system. But before fixing a date for bringing color into Canada there ought to be a full-scale technical investigation into the American setup.

If Canada can benefit from American experience in this field, all well and good. If that means holding off color TV in this country for a few more years, no one should worry. In the long run the CBC, the manufacturers and the public will benefit.

The increasing use of transistors during recent years has caused many people to feel that magnetic amplifiers are losing their place as amplifier elements in automatic regulators. This paper describes typical magnetic amplifiers and attempts to show them in their proper perspective as control elements, whether used in conjunction with transistor amplifiers or alone. Some circuit considerations are discussed and methods of improving the characteristics are suggested.

Dr. P. P. BIRINGER, P.ENG. & I. R. DALTON, P.ENG.*



Saturable reactors for 30 watt and 5 kw magnetic amplifiers

Magnetic amplifiers—latest trends

The magnetic amplifier is a rugged, reliable device requiring no regular attention. For this reason it has found extensive application in control systems, where these properties are as important as the electrical characteristics. Initially the magnetic amplifier was considered suitable only for a range of outputs from one to one thousand watts. Lately, however, it has found more and more applications in the higher power fields—one firm in Toronto has recently built units of several hundred kilowatts capacity. In the lower power range, up to about ten watts, the transistor amplifier complements the magnetic amplifier and works very well with it.

There are three requirements for a good magnetic amplifier and these must be satisfied to a greater or lesser degree according to the application. They are good power amplification, pronounced linearity of amplification and quick response to input changes. Unfortunately these three requirements conflict to a certain extent so that to accentuate one or two of these properties will require a compromise on one of lesser importance. In servomechanisms, for instance, high amplification and quick response are usually desired and good linearity may not be possible.

Circuits

The magnetic amplifier consists of an interconnection of saturable reactors, each having several windings, and so arranged that large currents in the output circuit can be controlled by small currents in the input, or control, circuit. Various methods of achieving appropriate characteristics, and some typical circuits are described below.

Feedback is used in all amplifiers to improve the amplification, at the expense of linearity. The principle underlying feedback, or self-excitation as it is called here, is that the output current, or part of it, is used to assist the control current, thereby reducing the power required by the control circuit. A reduction in required control winding ampere-turns of about one to twenty is normal for silicon cores, but with high quality core materials the reduction may be as much as one to two hundred. The simplest and by far the commonest way of achieving self-excitation is the use of rectifier elements in the output winding circuits, as shown in fig. 1 for example. This prevents the negative portions of the alternating supply voltage from demagnetizing the core and thus provides a premagnetization of the core in the correct sense to aid the control signal. This then is equivalent to positive current feedback. Obviously high quality rectifiers must be used to prevent demagnetizing currents.

The connection of a typical single-phase self-excited magnetic amplifier for alternating current output is shown in fig. 1. The instantaneous value of the load current is the difference between the instantaneous currents in the two elements. The control of output power is achieved by control of the point in each half-cycle at which a core saturates to allow the supply voltage to be applied to the load. This firing point depends on the initial level of the

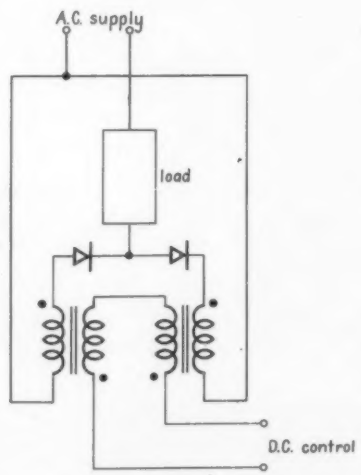


Fig. 1. Single-phase self-excited magnetic amplifier with ac output

*University of Toronto, Electrical Engineering Dept.

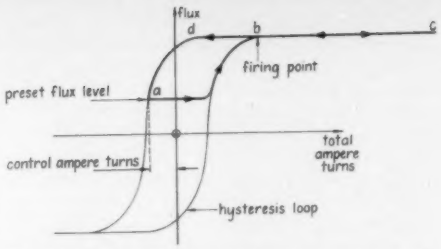


Fig. 2(a). Typical locus of flux vs ampere turns

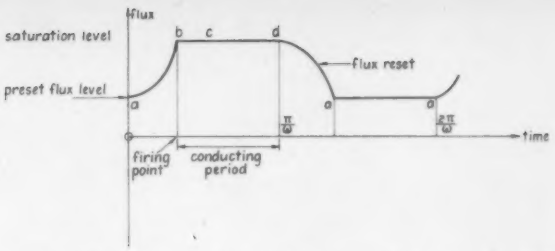


Fig. 2(b). Typical flux history corresponding to fig. 2(a)

core flux relative to the saturation level, and this initial flux level is reset in the half-cycle immediately preceding firing. A typical core flux locus is shown in fig. 2(a) and its time variation in fig. 2(b). To maintain the control current, power must be supplied to the control winding. Thus either the control current or the control voltage may be considered as the independent input variable, but the current is normally used. Fig. 3 shows a typical control characteristic in its usual form, relating output current to control current.

The shape of the transfer characteristic in fig. 3 should be noted. Due to the effect of the hysteresis loop on the preset flux level as shown in fig. 3, zero control current leaves the core in a nearly saturated state, so that nearly full output results. A separate bias signal would be required if the full range of control is to be achieved with unidirectional control signals. Even with a large negative control current, such that the supply voltage is entirely absorbed by the main windings, there is always a small alternating exciting current flowing in the output, as shown at the "cut-off" point in fig. 3. A larger negative control current produces initial saturation in the core and so alters the performance of the device. Operation in this region results in better linearity but much lower gain because self-saturation in this case constitutes negative feedback.

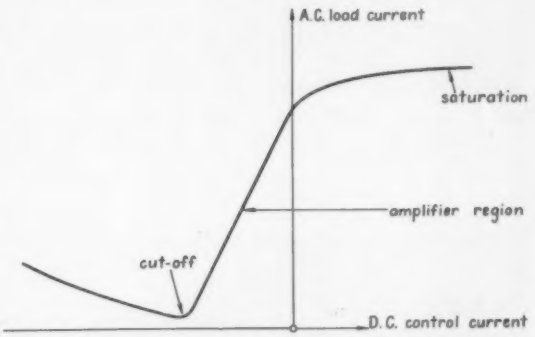


Fig. 3. Characteristic of self-excited magnetic amplifier

Other connections

The only way at the present to obtain a full control range from zero to maximum power output is to use two magnetic amplifiers in push-pull and bias them down to one half output or to cut-off. The use of dummy loads to couple two amplifiers to the actual load makes it possible to obtain output polarity reversal, but the efficiency of such a circuit can never exceed 50%.

Present research work at the University of Toronto indicates that very efficient control can be obtained throughout the complete output range by using static frequency multipliers (another class of saturating core device) in simple circuits instead of magnetic amplifiers. In some cases special higher frequency load devices must be employed.

For a unidirectional output the basic circuit would be as shown in fig. 4. Such a circuit, perhaps with a transistor pre-amplifier, takes the place of a vacuum tube power amplifier. The size of the core unit is comparable to that of the output transformer required in the electronic circuit. Efficiencies of 70% for small sizes and 85% for large units are usual, as compared with about 50% for vacuum tube amplifiers in Class B operation. These advantages, combined with the rugged nature of the device, give it a tremendous superiority in many applications.

For the control of large power in direct current systems, polyphase magnetic amplifiers are preferred for the following reasons: they give symmetrical loading on the line, more efficient utilization of rectifier elements and less

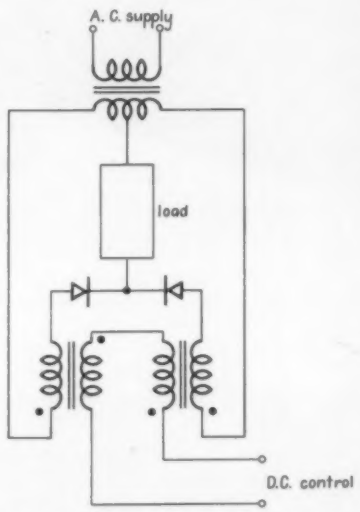


Fig. 4. Single-phase self-excited magnetic amplifier with dc output

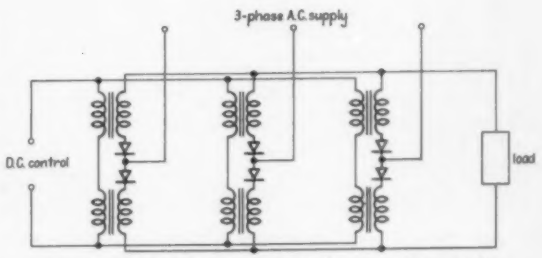


Fig. 5. Three-phase self-excited magnetic amplifier

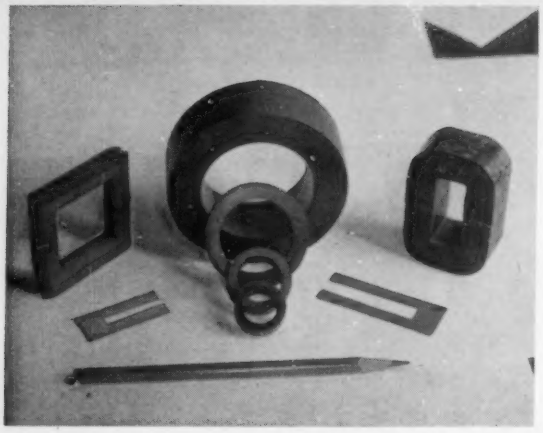


Fig. 6. A sintered core, tape wound toroidal cores, wound-and-cut "C" core and special core stampings for reactors

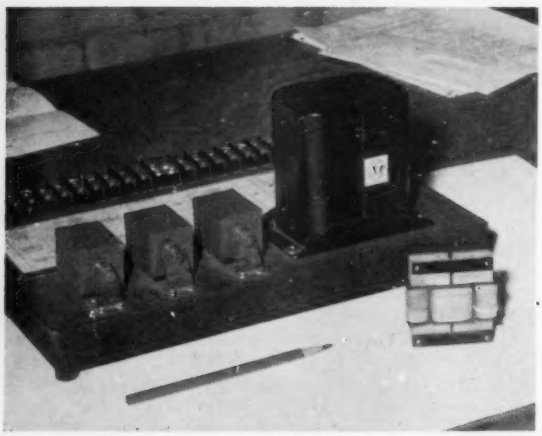


Fig. 7. A commercial magnetic amplifier showing the reactor and rectifiers. In front is a bare reactor of similar type

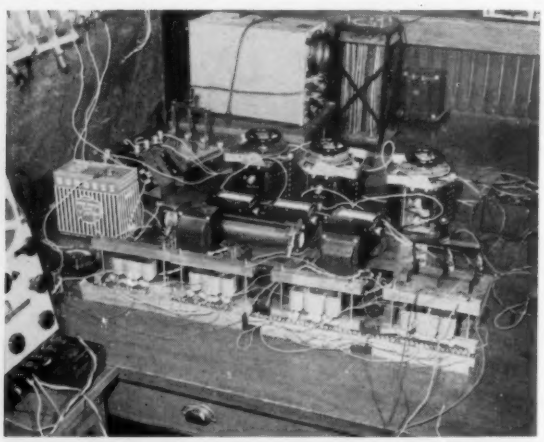


Fig. 8. Some of the experimental work on saturable magnetic core devices being done at the University of Toronto

ripple on the output. The possible circuit configurations are essentially those of polyphase controlled rectifiers, and the variations are almost unlimited. A three-phase bridge-type circuit is shown in fig. 5 as an example. Generally speaking, in polyphase connections there is less harmonic content in the control current and the power gain/response time ratio is higher than in single-phase circuits.

The response time of a self-excited magnetic amplifier characterizes the response of the output to a step change in the control variable. A change in the preset flux level, with an accompanying change in output voltage, cannot be obtained instantaneously by a change in control voltage. The inductance of the control windings delays the build-up of the control current, and in no event can the output show a change in less than one-half period of the supply, due to the cyclic nature of the process. This minimum can be obtained using special connections with low power gain, but the self-excited magnetic amplifier will have response times far in excess of this figure. An attempt to improve the control circuit time-constant by an increase of resistance results in a higher power consumption for the same control current and a consequent lower power gain. For 60-cycle units power gains of 200 to 2,000 per stage and response times of the order of 0.05 to 0.1 seconds are typical. Circuits with one-half cycle response times normally have gains of only 50 to 100 per stage.

Improving the dynamic properties

There are several ways of improving the response time and still keeping the high power gain. The first and most often used method is the cascading of several stages. This method requires push-pull stages and careful voltage control for the bias and supply. It is economical only at low power levels because of the poor efficiency of the push-pull stage. The load power will not be higher than about 17% of the combined power rating of the component amplifiers if proper dummy loads are used.

A second method uses a high supply frequency. The higher frequency requires fewer turns in the windings and this results in a reduced inductance for the control windings and hence a shorter time-constant. As an example of the advantage of this method a self-excited magnetic amplifier to have a power gain of 100,000 can have a time constant as low as 0.06 seconds if the carrier frequency is 5,000 cycles per second. The economic problem of having a high-frequency generator for the sole purpose of driving a few magnetic amplifiers can be solved by using small frequency multipliers, driven from the supply line.

A third method of improving the response involves the use of a pre-amplifier stage of a pentode or transistor as a current source so that the control winding time-constant has no effect. This of course also reduces the signal power requirements by the ratio of the pre-amplifier gain.

Conclusion

No attempt has been made at an exhaustive treatment of magnetic amplifiers in this article. Rather they are accepted as working and reliable amplifiers which can be used in many servomechanism applications. For large power outputs and medium power gain they can be operated very economically without any other special equipment. In cases of high power-gain requirements one must use the highest possible gain/response time ratio to avoid undesirable oscillations in the system. Three methods of achieving this—two of them fairly recent—have been described. The development of static frequency multipliers and transistors further extends the range of possible applications of magnetic ampliers. END

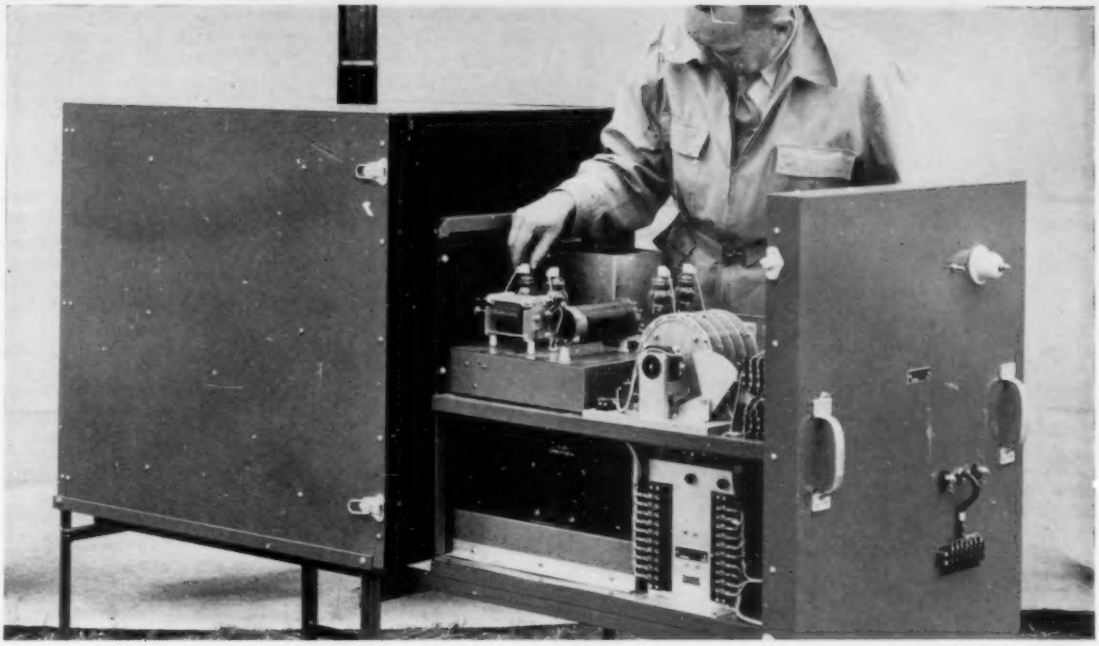


Fig. 1. Beacon withdrawn from the thermostatically controlled heating cabinet and resting on service racks

Increased shipping in Arctic waters made more navigational aids a necessity. To meet the need a transponder radiobeacon was developed which would operate at temperatures well below freezing without any attention for a period of over four months. The beacon can be interrogated by ships up to a range of 60 miles.

W. M. CAMERON*

Transponder radiobeacon means safer navigation

Navigation in the Arctic North, through the Hudson Strait and among the shoals of the Hudson Bay, has always been a hazardous undertaking. Visual beacons, such as lighthouses and lighted buoys, are of great value in clear weather but cannot be used when fog sets in. Manned radio stations are extremely costly to establish and maintain. To meet these problems and provide increased navigational aids in Northern waters the National Research Council developed an unmanned transponder type of radiobeacon.

Radiobeacons transmit a signal, coded for identification, by means of which a ship may obtain a radio bearing by the use of her radio direction-finder. The ship's position can be established by cross bearings on two or more beacons. Most radiobeacons transmit on a clock-controlled schedule; some operate unattended and are visited only when service and supplies are needed. The clock-control is quite simple and dependable. It is not very economical, however, as the beacon operates whether or not such transmission is required, but this is a matter of small consequence if the beacon site is easily accessible.

Only three isolated and widely spaced radio stations, with a fourth at Fort Churchill, were available as marine navigational aids in the Eastern Arctic before 1953. Considering the increasing volume of shipping en route to and from Fort Churchill, and the hazardous passage through the Hudson Strait and among the shoals of the Hudson Bay, the possibility of unmanned radiobeacons as further navigational aids was investigated. The transponder type, which supplies a beacon signal only when interrogated, provides better service and has a lower power demand than those transmitting on a clock-controlled schedule.

*National Research Council, Ottawa

Wide range of temperatures

Although transponder radiobeacons have had limited applications in the past, such a radiobeacon, suitable for operation in Arctic areas, must meet the following specifications: it must operate reliably at ambient temperatures considerably below freezing and it must also be capable of unattended operation over a four-month period, as Arctic beacon sites are not easily accessible.

For these reasons, batteries are used to power both the receiver and transmitter in the interests of reliability. Features which also contribute to reliable operation are the use of two complete groups of transmitter tubes, each of which functions alternately on successive beacon cycles; and dual receivers having separately excited mixers and paralleled dc amplifier stages.

Four six-volt automobile type lead-acid batteries are

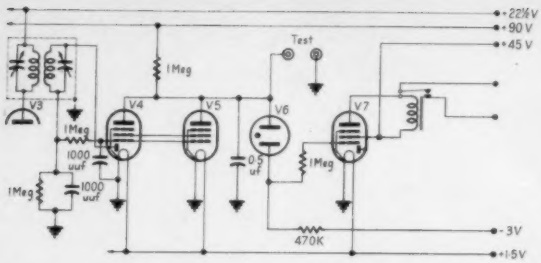


Fig. 2. Circuit diagram of part of the low-drain receiver

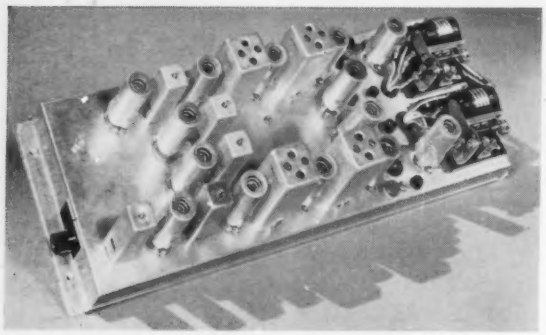


Fig. 3. The receiver. Batteries keep it going for 4 months

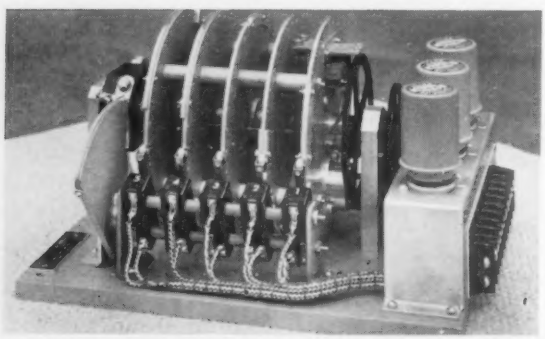


Fig. 4. The selector is driven by a constant-speed motor

Landing equipment from the supply ship for Charles Island

used for transmitter power because of the high current demand of the motor-generator. These are on continuous trickle-charge from a bank of wet primary cells. Two wet primary cells are used to light the receiver filaments and all of these batteries are sheltered in a "dog house" adjacent to the beacon unit.

The entire beacon station, including receiver ht batteries, is enclosed in a multi-shell insulated enclosure shown in fig. 1. The enclosure is heated by a gas flame, which is controlled by a thermostat. It is housed in a small prefabricated hut. Two tanks of propane constitute an ample supply of fuel for the season. New batteries and fully charged propane tanks are installed once yearly when the supply ship visits the beacon site at the opening of navigation.

Four months operation

The beacon was a joint project involving the National Research Council and the Department of Transport. General design and construction, as well as the development of special components was undertaken by the National Research Council. The Department of Transport furnished items such as the transmitter and motor generator, the keyer unit and the gas burner for the heating system.

The receiver remains in continuous operation throughout the Northern season of navigation, about four months. It is normally connected to the antenna system through a change-over relay. The receiver output relays energize the selector when a signal is received.

On the receipt of a pre-arranged interrogation signal, the selector provides a switching sequence to operate the beacon transmitter. The keyer unit, which determines the characteristic signal of the beacon, draws only a few milliamperes and therefore operates continuously. Transmission continues for four minutes to allow the interrogating station to obtain a radio bearing on its direction finder. The selector resets at the end of beacon operation and awaits further interrogation.

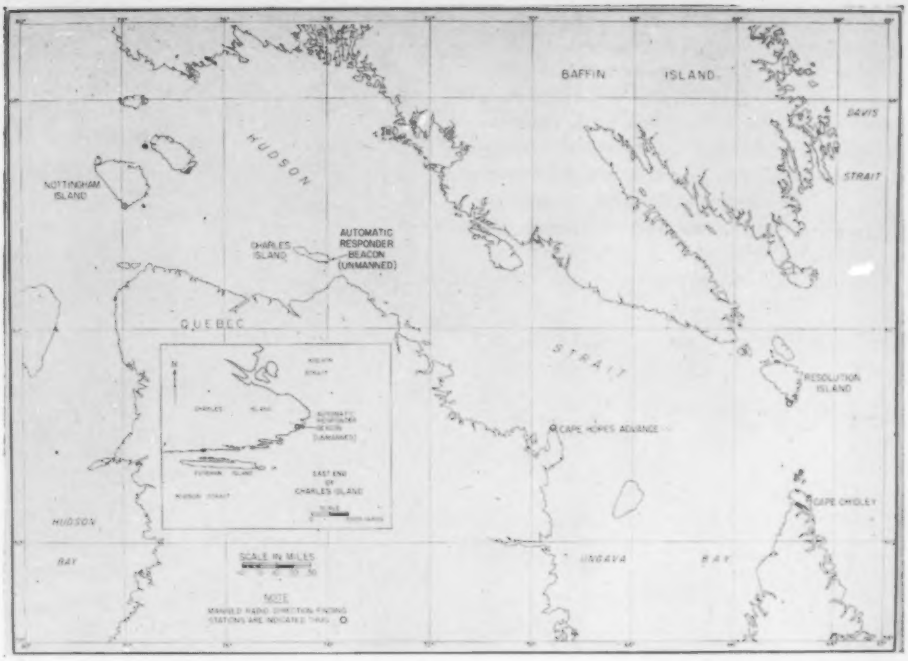
The auxiliary panel serves as a convenient distribution and test panel, as well as a mount for small components. A small magnetically-driven counter which records beacon transmissions is included.

Low-Drain Watchkeeping Receiver

The development of a reliable receiver of adequate sensitivity and low power demand was a prime consideration. Fig. 2 shows part of the circuit diagram of the final model. The r-f and i-f sections are quite conventional with the exception that a separately excited mixer is used. This was found to be much more reliable than a self-excited stage involving a low-drain filament-type tube.

A double time-constant in the plate circuit of V4 and V5 ensures freedom from morse code interference. Negative bias is developed by the detector on signal and this drives the grids of V4 and V5 to cut off. The large condenser in the plate circuit of these tubes charges slowly through the one megohm plate resistor. On the termination of signal, V4 and V5 are again conducting and the condenser discharges rapidly through a low resistance which is equal to the reciprocal of the combined transconductance of the tubes. Hence, a sustained signal of about one-half second is necessary to operate the relay tube and close the relay, which releases a few milliseconds after the cessation of a signal.

When conductive coupling is used between dc amplifier stages, the cathode of one of the stages must be at some potential far above ground to obtain the necessary bias conditions. This method requires that the ht on at least one stage be increased. Additional battery requirements, necessary when tubes having directly heated cathodes are used, prohibit the conventional approach and some unorthodox dc coupling method must be devised. The neon tube, V6,



Beacon was installed by Department of Transport on Charles Island in the Hudson Strait. Map shows site of the beacon which is now an important aid to navigation in an area where pack ice may force a ship miles off its proper course

provides dc coupling to V7. This circuit has the added advantage that, when V6 fires, positive bias is applied to V7 and the relay comes in solidly.

The ultimate sensitivity of this receiver is 8 to 10 microvolts signal input to close the receiver relay. An input attenuator provides reduced sensitivity settings of 10, 20, 30 and 50 microvolts. Two identical receivers, having a common input circuit, and with output relays paralleled, were built on a single chassis. Fig. 3 shows the receiver. The filament drain for each superheterodyne is 0.35 amperes at 1.4 volts, while the ht requirements are 90 volts at 2 milliamperes, 22½ volts at 2 milliamperes and, when V7 closes the relay, 45 volts at 2 milliamperes.

One wet cell, three heavy-duty "B" batteries, and a small "C" battery for each superheterodyne are of ample capacity to keep the receiver in continuous operation over a period of four months. Now it would be possible to transistorize the receiver with a reduction in power supply requirements, but this could not be done when the receiver was developed.

Interrogation signal

A slow interrogation signal was chosen, which made the design of a selector quite simple, as shown in fig. 4. A constant-speed motor turns the cam drum through a magnetic clutch against the action of a spring. The clutch is released at the end of the beacon cycle and the spring returns the drum to "ready" position. The drum return is slowed by an air brake.

On completion, the receiver and selector were put on board the NRC experimental ship "Radel II" for range tests. Reliable operation was experienced at a distance of 90 miles when interrogated on a frequency of 500 kc by a 35-watt transmitter during daylight hours. These two units were then given a six month reliability test. They were successfully interrogated a number of times each working day during this period and were then built into the equipment.

The beacon was installed by the Department of Transport on Charles Island in the Hudson Strait. Although the nominal maximum range for direction-finding is specified as 60 miles, it is interrogated and checked daily throughout the season of navigation by Cape Hope's Advance Radio over a distance of 180 miles.

A few mechanical faults have occurred but with the present practice of yearly overhaul, reliability should be of a high order.

The beacon may be called into operation by an interrogation signal, consisting of two 10-second dashes spaced 20 seconds, transmitted on a frequency of 410 kc. The signal, after detection and amplification closes relays which actuate the selector. When the selector identifies the interrogation signal, it provides the necessary switching for transmission. The beacon then operates for four minutes on a frequency of 298 kc. The characteristic is the morse letter "C", repeated three times and followed by a four-second dash.

The beacon is very popular with shipmasters sailing in this area, where pack ice may force a ship many miles off course with little warning. Its importance as a navigational aid was established in the first year, when it operated on an experimental basis. Altogether 54 transmissions to interrogating ships were recorded during that season. END

Some of the terrain over which equipment was carried

Waveguides and coaxial cables have replaced ordinary wire conductors at microwave frequencies. Similarly, new types of measuring instruments have proved necessary because of the phenomena which occur at these high frequencies. Calorimetric techniques of microwave power measurement are described in this article, with details of the dummy loads used for the various frequency bands and an examination of the accuracy which can be obtained.

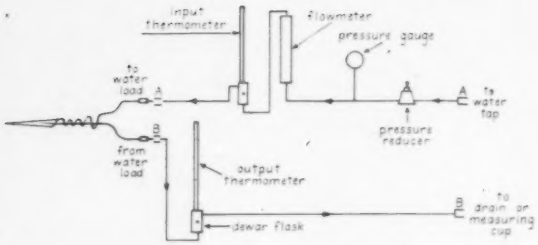


Fig. 1. Schematic diagram of a complete calorimeter system

Fig. 2. Single control calorimeter handles all power levels

Calorimeter makes microwave power measurement easy

SAMUEL FREEDMAN*

As the radio-electronic art advanced to higher frequencies and shorter wavelengths, the behaviour of a wire and a capacitor reversed in electrical behavior. Where, in the case of dc and low frequency ac, a wire conducts and a capacitor isolates energy, the exact opposite occurs in the case of microwaves. On the other hand, radiation in a small area has increased because it can physically accommodate the wavelength.

A simple explanation is to say that at microwaves, the "wire is an insulator" and the capacitor is a "short circuit." That being the case, ordinary meters and instrumentation containing wire can no longer be used satisfactorily to measure power. There are much simpler and more reliable methods working with the actual energy radiation.

If liquid in a container is put inside an energized waveguide or coaxial cable, it will completely absorb all the power present and its temperature will rise. If the liquid is circulated, the heat rise will be by a constant amount rather than cumulative. The power measurement in calories per minute will be equal to the temperature differential (before and after r-f exposure) in degrees centigrade multiplied by the flow rate in cubic centimetres per minute, and if the liquid is other than water (specific heat unity), further multiplied by the specific heat of the liquid employed. Each 14.334 calories per minute is one absolute watt of power, regardless of frequency.

This liquid in a container—a dummy load—with a pair of thermometers and a flowmeter is called a calorimeter or calorimetric wattmeter. The power measured or absorbed is the average power whether it is cw, modulated or pulsed.

System described

A complete system designed for water tap or accessory reservoir operation is shown in fig. 1. The water enters and is both stabilized and reduced in pressure by a "pressure reducer" to something between zero and about 10 pounds depending on the power to be measured or absorbed. This flow is indicated on a moving float type of Flowmeter. It then goes to the input thermometer. This has a helical coil type mercurial reservoir sealed in a Dewar Flask at its base and is far more sensitive and accurate than normal thermometers.

The path through the Dewar Flask receptacle is designed to keep liquid sequence correct (first water in is first water out). It also keeps the liquid path continuous even down to a few drops a minute to permit the thermometer's use at minimum as well as medium and maximum power. The mercury indication reflects against a built-in capillary mirror which provides magnification, colored contrast and directivity so that readings are easy to make.

From the input thermometer, the liquid continues through a snap-on fitting type of valve to a glass tapered load housed in a waveguide or coaxial cable. There it meets the r-f energy source to be measured, gradually absorbing it in sinusoidal fashion. The heated liquid continues to the output thermometer (identical to the input thermometer)

*Chemalloy Electronics Corporation, Santee

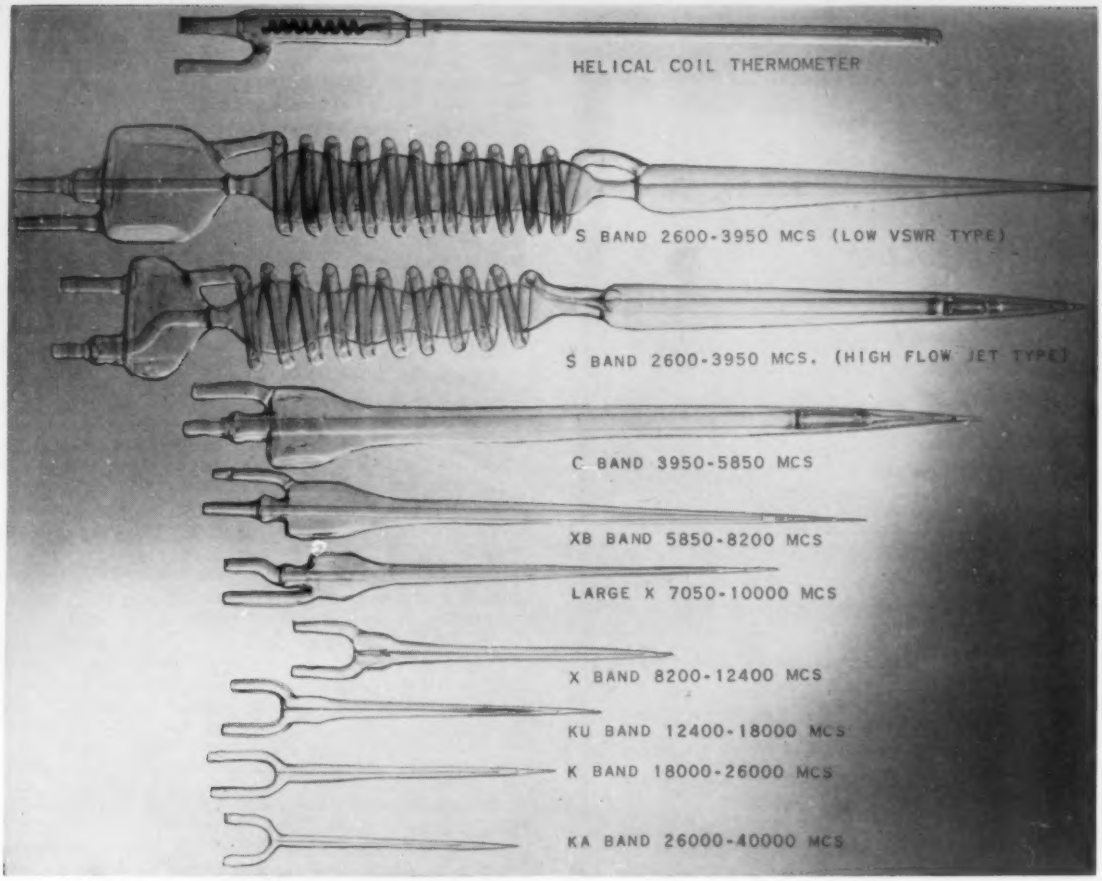

HELICAL COIL THERMOMETER
S BAND 2600-3950 MCS (LOW VSWR TYPE)
S BAND 2600-3950 MCS. (HIGH FLOW JET TYPE)
C BAND 3950-5850 MCS
XB BAND 5850-8200 MCS
LARGE X 7050-10000 MCS
X BAND 8200-12400 MCS
KU BAND 12400-18000 MCS
K BAND 18000-26000 MCS
KA BAND 26000-40000 MCS

Fig. 3. Helical coil thermometer and dominant mode waveguide loads for frequencies between 2,600 and 40,000 mc

where it will show a higher temperature depending on the power absorbed and the flow rate. The liquid has now completed its cycle. It may then be expended or returned to a reservoir, recooled and reused.

A single control calorimeter system is shown in fig. 2. This instrument can handle any level of power. Changes for frequency bands are made by connecting the appropriate load, either coaxial or waveguide.

Optimum shape and size

Details of the helical coil thermometer and of various waveguide loads between 2,600 and 40,000 megacycles are illustrated in fig. 3. These loads are known as "dominant mode" types in that an optimum dimensioned and configurated load exists for each frequency band. This eliminates the need for tapered adaptors or transitions with a common load for higher frequency bands. The efficiency of the dominant mode load can be up to ten times better than non-dominant mode types depending on the amount of transition involved.

The basic concept of the waveguide load is a sharp tip flaring out gradually to the full internal diameter of a waveguide in six or more physical wavelengths of dimension. Since water has a dielectric constant of 81, the use of water instead of air or gas medium means that the wavelength shortens nine times (by the square root of the dielectric constant). Therefore, the length of the load is 54 wavelengths when water-filled. It is necessary, to obtain high accuracy, that the load should be many wavelengths long. The power is absorbed sinusoidally, most of it going in the first half-wavelength. By the time energy has traversed the length of the simpler loads shown in fig. 3, it is attenuated 60 db and only one millionth of the energy remains. In the case of the more elaborate S Band load illustrated the energy is attenuated about 80 db.

A load needle pointed and flaring out to the full internal diameter of a waveguide in six physical or 54 electrical wavelengths will have an inherent VSWR of 1.03, varying from about 1.025 to 1.04 depending on how the first water tip intersects the oncoming sinusoidal energy.

The S Band load illustrated for the 2,600-3,950 mc band has been made more elaborate so that it can be used with different mode adaptors. Such a load configuration in tests has been found to have a low VSWR all the way up to 55,000 megacycles except in a limited region around 12,000 megacycles caused by the glass coil connection where it meets at the back of the tip section. Such a load is really three loads in one. The first load is the coiled section three wavelengths long. The second load is the tip section three wavelengths long. The third is the wafer section (within the coil section), also about three wavelengths long. This mixes the liquid before emergence and prevents a waveguide path within the coil so that no unabsorbed energy can escape.

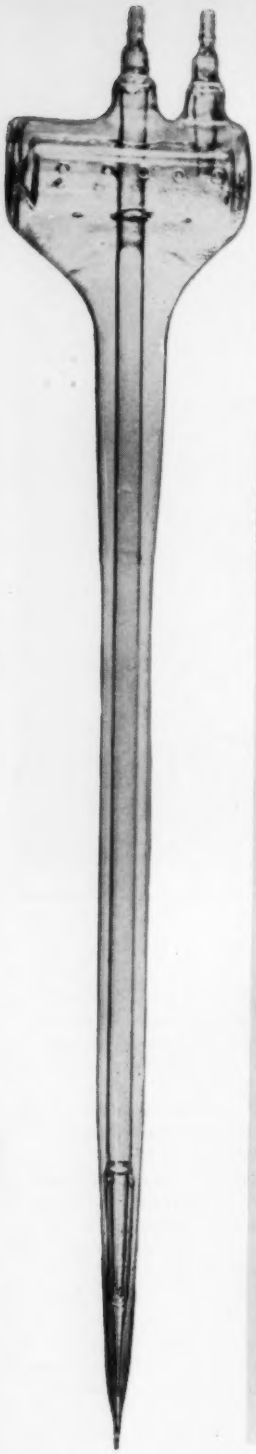


Fig. 4. The feasible physical limit for low frequency waveguide loads is in the L Band, 1,100 - 1,700 mc per second, as shown here

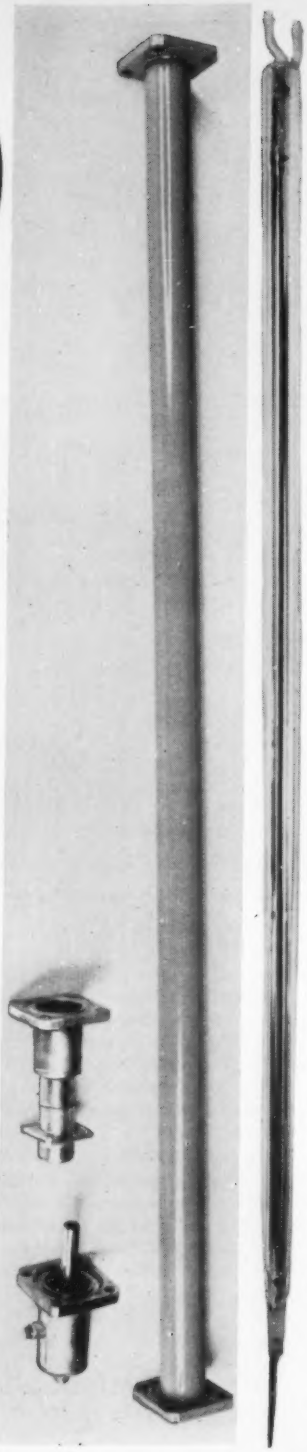


Fig. 5. A coaxial load, extreme right, which is interchangeable with waveguide loads and will operate as low as about seven megacycles. Outer casing and coaxial fittings are shown at left

Double jet

In fig. 3 two of the loads have a double jet within the tip section. This is to handle very high flow rates at low water pressures in extremely high radar power situations. As the flow increases some water turns about at the first jet, more turns about at the second jet and the balance at the tip where some water must always be made to circulate. The tip water will heat the most, the second jet less and the first jet still less. These three water temperatures all mix and average up before emerging from the load to give a true temperature reading at the output thermometer. Enough flow to measure 5,000 watts average power at five megawatts peak power is possible with about 10 psi water pressure.

In order to ensure that steam will not form at the tip because of the small amount of water available there to meet the bulk of the energy, this jet system has been made very efficient. When removed from its outer housing, it can shoot a stream ten feet ahead and four or more streams five to six feet laterally. The jet has been streamlined so that it does not seriously increase the VSWR or spoil the gradualness of the taper. This S Band load with a jet may have a VSWR of about 1.06 or .02 to .03 higher than the non-jet type.

The feasible physical limit for low frequency waveguide loads is in the L Band 1,100-1,700 mc (fig. 4). A load that might contain a few drops of liquid for the Ka Band (26,000-40,000 mc) might scale up to over a gallon at the L Band since dimensions increase in three planes. The L Band load cannot, therefore, measure very low power but it can get down quite low by the use of internal voids which reduce its internal volume.

Coaxial loads

A coaxial load for liquid use (fig. 5) is interchangeable with waveguide loads. The coaxial housing contains a glass load terminated with Type N or other type coaxial fitting as required. The far end of the load has a water inlet and outlet to connect to the calorimeter.

The coaxial load is four physical wavelengths for 1,000 megacycles. Water raises this to 36 electrical wavelengths. A pressurization end plate acts as an energy reflector and makes it equivalent to 72 electrical wavelengths. At 10,000 megacycles, it will be 720 wavelengths and at 100 megacycles 7.2 wavelengths. The limit of low frequency operation is considered to be half an electrical wavelength or about seven megacycles.

In the case of coaxial loads, the load itself may be more efficient at higher frequencies than lower frequencies thereby helping to compensate for the fact that coaxial fittings to it are declining in performance with increase of frequency. A common mis-statement made is that coaxial calorimeters function from zero frequency upward. Obviously at one cycle, the wavelength is 186,000 miles long so no load would represent any appreciable part of a wavelength. Being unrelated to wavelength, the usefulness of a calorimeter at or near zero frequency is very questionable.

Glass has advantages

Glass is used as the load material because it is both r-f transparent and a good conductor of heat. Plastic or Teflon loads have a lower dielectric constant and are more r-f transparent but they are poor conductors of heat and melt or deform at much lower temperatures than glass. There are no known plastic loads which have been able to survive very high power indefinitely. Some have exploded out of waveguides and most of them under the influence of high power melt at positions corresponding to energy nodal points. Glass being a good conductor of heat

and able to withstand over 1,000 degrees F, gives up any heat resulting from its higher dielectric constant back to the water almost immediately. Also glass is cheaper to fabricate in the small quantities and many sizes or versions needed by the art.

A three control type of calorimeter is shown in Fig. 6. Two pressure reducers are employed in tandem. The first "Coarse Flow" is preset to reduce the incoming pressure down to whatever maximum is needed, for example 10 psi from up to 150 psi. The second regulator "Vernier Flow" is then used as a single control. The "Zero Flow" Control is a toggle valve to cut off the flow entirely to permit the detection of the feeblest energy in extreme cases.

By shutting off the flow with this latter control and then turning it on, the heated water in the load tip is circulated to the output thermometer. This control is also a means of using the calorimeter system as an arrangement to heat up liquids by any desired amount, and is helpful in pulsing the system to drive out trapped air or lodged residue.

A reservoir and cooling unit can be used as a source of water supply. This unit minimizes water friction and cools water about 25 times faster than is needed for circulating through the calorimeter. The unit can provide a gravity feed so that there will be no pump turbulence when measurements are made at low power.

Analysis of errors

There are five types of errors in a calorimeter. Fortunately they are not in the same direction so they partially balance out. These are:

1. Specific heat of liquid error. The computation is based normally on water having specific heat of unity. That would only be true for pure water remaining pure. This cannot happen indefinitely as the water will draw impurities from its own container or path. If 10 watts, for example, measures 143 calories using pure distilled water, and 145 calories using tap water, then the specific heat of the liquid used is 143/145 parts of unity. In practice, this means the calorimeter will read slightly high on temperature and calory count. The reading will be approximately equal to and opposite in direction to the VSWR error of the load.

2. VSWR load error. A typical load with a VSWR of 1.03 has a loss of .226 parts of one percent. This will show on the calorimeter as a temperature reading lower than true. Therefore, the specific heat and the load VSWR errors being opposite in direction largely balance out. The final error is so small that it cannot be measured.

3. Flowmeter error. This is caused by the moving float necessary in flowmeters and can be eliminated by measuring the exit water directly with a measuring cup.

4. Thermometer error. Standard thermometers in calorimetry are either 10-65 degrees C (10 divisions per degree) for maximum power levels, 10-35 degrees C (20 divisions per degree) for medium power levels, or 18-28 degrees C (50 divisions per degree) for primary standard work in temperature-controlled working spaces. They are accurate to a fraction of a division. As they age, they may change in calibration a few hundredths of a degree. Since they have been made with the same aged glass and triple-distilled mercury and by the same craftsman, the error is expected to be the same in both of them. They should maintain a proper temperature differential indefinitely. Tests made at six-month intervals show the error was .01 to .02 degree. Each thermometer is individually calibrated. In practice, thermometer calibrating and reading error may average in the order of plus or minus 0.1% in good calorimeter systems.

5. Heat radiation error. This is negligible when a high flow rate and low temperature change is used. It can be eliminated altogether by merely plotting power vs temperature differential for two or more flow rates and extrapolating to zero degrees temperature differential. With this method, the distance between the instrument and the apparatus of which the power is to be measured can be very great, limited only by the distance where no temperature differential whatsoever remains when the liquid returns to the output thermometer.

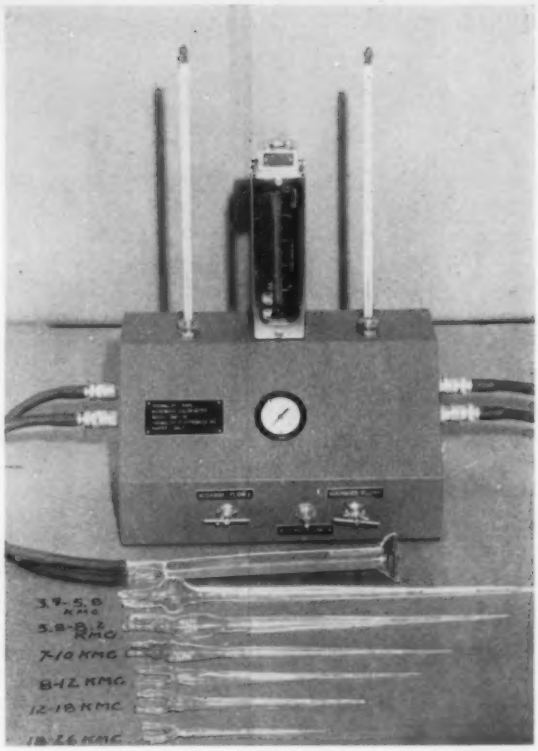


Fig. 6. Three-control calorimeter has two pressure reducers

The time it takes to make a measurement and stabilize the reading is the time it takes the liquid to traverse from the input thermometer through the load back to the output thermometer. For a high flow rate and short load and connections, it is as fast as the eye can see. For a low flow rate, large load and long connections, it may take several minutes. Under usual conditions of practice it is a fraction of a minute.

Accuracy 0.5 percent

Highest accuracy, in the order of half of one percent, can be obtained under any of the following circumstances:

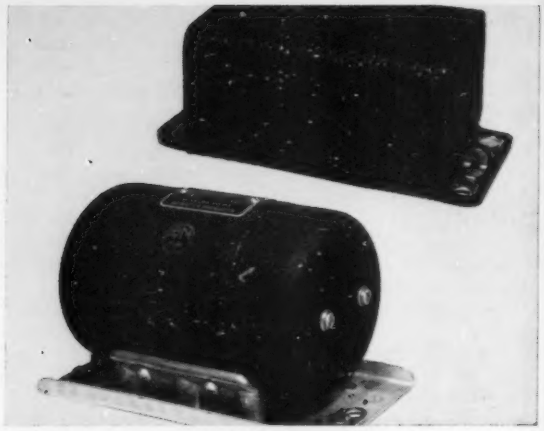
1—Higher frequency bands, where liquid volume is least.

2—Higher flow rates, where heat radiation is least.

3—Higher powers, where flow and thermometer responses are more appreciable to read.

At errors somewhere between one-half and two percent, practically all the required measurements of power can be reliably measured. This compares with up to 2 db or more (38%) error in non-calorimetric devices. The great advantages of a calorimeter are its ability to handle power at its natural level, regardless of magnitude, and to do it without cumulative heating. By reverse usage, the same setup can also serve as a temperature standard, flow standard, specific heat of liquid standard and even a heat radiation standard. END

View of 200 volt, 200 ma dc transistor inverter power unit with cover removed shows layout. Input is 25-29 volts dc



Dynamotor in front with, behind, the equivalent inverter unit which has greater efficiency, one-fourth the weight

Transistors take over

Big advantages of inverter power unit over dynamotor

Transistors are moving into every field. This article describes design work that has produced transistor inverter power supply units which have many advantages over electro-mechanical inverting equipment. Following a description of the technical operation of the circuit and an account of the packaging techniques used, the authors deal with its electrical characteristics and the environmental conditions under which it can operate.

J. W. BATES, A.M.BRIT.I.R.E. & J. SANJANA, P.ENG.*

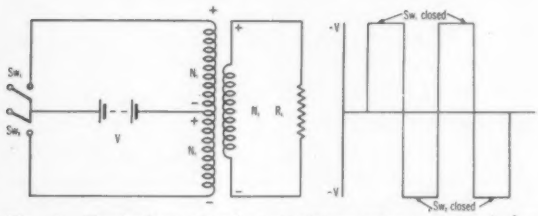


Fig. 1. Equivalent circuit: transistors operate as switches

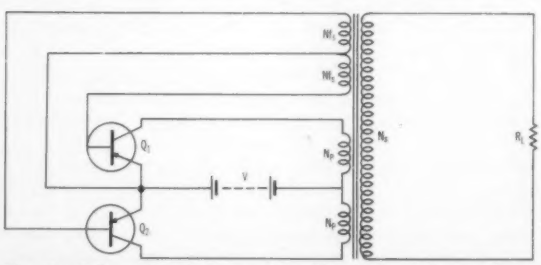


Fig. 2. Schematic diagram of oscillator shows basic circuit

Using modern power transistor technique and applying packaging experience gained in guided-missile engineering, a rugged, lightweight, transistor inverter power supply was developed. It is for use in airborne electronics and other highly mobile equipment.

This, however, is only one application of many. It fits equally well into the lighting, communication, high speed motor and computer field. Experimental work has been done in the application of the transistor inverter to ultrasonic soldering, portable drills, and to the process of ultrasonic cleaning.

The transistor inverter can be used as a direct replacement for mechanical inverters employed so extensively in the past as a source of h-t voltage from low voltage dc supply. To the designer the use of this unit offers weight and size saving features.

Circuit operation

In the circuit the transistors operate as on-off switches, This circuit can be represented as in fig. 1.

The switches operate such that when SW_1 is closed SW_2 is open and vice versa. With SW_1 closed the battery voltage is applied across the top half of the transformer primary. This produces the voltages with the polarities as indicated in fig. 1.

When the switches are reversed the battery voltages will be across the bottom half of the transformer primary which will result in a reversal of all voltage polarities. Thus when the switching time is sufficiently fast, a square wave voltage is obtained across the load resistance.

The oscillator circuit is shown in its basic form in fig. 2. The simplified theory of operation of this circuit is as follows: Assume transistor Q_1 is conducting. This places the battery voltage across the top half of the transformer primary resulting in a constant

$$\frac{d\phi}{dt} \quad \left(V = N\frac{d\phi}{dt}\right).$$

*Canadian Westinghouse Company Ltd., Hamilton

The polarity of the feed back winding holds Q_1 conducting and Q_2 cut off. When the transformer core saturates,

$$\frac{d\phi}{dt}$$

falls to zero and consequently the feedback voltage falls to zero.

$$\frac{d\phi}{dt}$$

then reverses since there is no conducting transistor to sustain the magnetising current. This change in the sign of

$$\frac{d\phi}{dt}$$

induces a voltage of the opposite polarity in the transformer. This voltage is applied via the feedback windings to the base of Q_2. This voltage starts Q_2 conducting and holds transistor Q_1 off. If the magnitude of flux at which this reversal occurs is ϕs, the frequency of the square wave is determined as follows:

During each half cycle

$$\left(t = 1/2f\right)$$

the flux changes linearly (for all but a small portion of the cycle) by an amount $2\phi s$ ($+\ \phi s$ to $-\ \phi s$).

$$\therefore \frac{d\phi}{dt} = \frac{2\phi_s}{1/2f} = 4f\phi_s$$

$$Vcc = Np\frac{d\phi}{dt} = 4fNp\phi_s$$

$$\therefore f = \frac{V}{4Np\phi_s} = \frac{V}{4NpB_sA} \text{ ------ (1)}$$

Common emitter used

In design work the common emitter circuit proved the most satisfactory of the three circuits — common base, common collector, common emitter — tested and was adopted as the circuit to be used for the two units.

This circuit was preferred because it requires less input power than is necessary for the common base and common collector circuits. Hence the transformer efficiency is higher for the common emitter circuit.

Hypernik V, Hypersil C-cores, Hymu 80 and Supermalloy cores were tried to ascertain the best core material for the transformer design. As a result of these tests it was found that Hypernik V gave the best switching waveform and efficiency. However any magnetic material which does not have an appreciable rise in flux density after saturation is suitable.

The operating frequency which will minimize losses in the transformer and transistors is the one to be chosen. This frequency is determined by core material, smoothing and decoupling.

Experimental results were noted and plotted as shown in fig. 3. It was found that the optimum operating frequency was 1200 cps. The primary turns are calculated from a modified form of the basic formula (1). The modified formula is as follows:

$$Np = \frac{0.98 \times V \times 10^8}{4B_sAfQ}$$

where Bs = saturating flux density
A = cross section area of core
f = desired frequency
Q = Toroidal winding factor (90%)

The feedback winding turns are a direct ratio of the turns/volt on the primary. Care must be taken not to overdrive the transistor as this will cause high dissipation

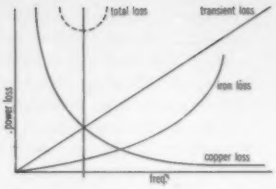


Fig. 3. Experimental results were used to determine optimum oscillator frequency of 1,200 cps

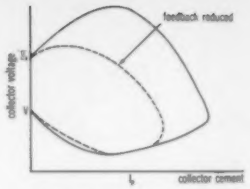


Fig. 4. Plots of collector voltage against collector current show effects of reducing the feedback

in the transistor as can be seen from the current locus (fig. 4).

Hence the feedback turns were kept to a minimum consistent with good starting and overload protection. The secondary turns are a direct ratio of the turns/volt on the primary neglecting the IR drop. For rugged construction the transformer was potted in Araldite. The connections were brought out through a header in the base plate.

The transformer Hypernik core is strain sensitive but the core material is housed in a Teflon case and embedded in Silicon grease. Before starting development the core was tested for shock and vibration. The core withstood a 30g shock along all three axes and withstood a vibration of 0.06 max. excursion at 10 to 55 cps without any deterioration in performance.

Temperature tests

The choice of transistor was based on the requirement of a transistor which has a low saturation resistance and a high dissipation rating. Several transistors listed met these requirements. However, only one was available in production quantities at a reasonable price. This was the Delco 2N174 power transistor.

Tests made at high and low temperature showed that the transistors were suitable for the environmental conditions specified. Although no difficulty was experienced in getting the oscillator to start with a resistive load, difficulty was experienced when the smoothing filter circuit was included in the circuit. This was due to the fact that the filter capacitor was uncharged on switch-on and hence the output circuit was virtually a short circuit with only the forward resistance of the diode in series.

Several methods of starting were used. The first method used was in the inclusion of a saturable choke in the secondary circuit. The choke presented a high impedance on switch-on and saturated at when the load current was drawn. This method was successful but was not used because it made the chassis construction bulkier and more expensive and because a heavy ringing voltage was developed across the choke which was reflected back to the transistors causing the base to collector voltage to rise above the permissible value.

The second method was the inclusion of a high resistance which is shorted by a relay when load current is drawn. This method also worked satisfactorily but again made chassis construction bulky and was expensive. The final method was effective at all environmental temperatures. In this a forward biasing resistor was included between the negative terminal of the battery and the base of one transistor.

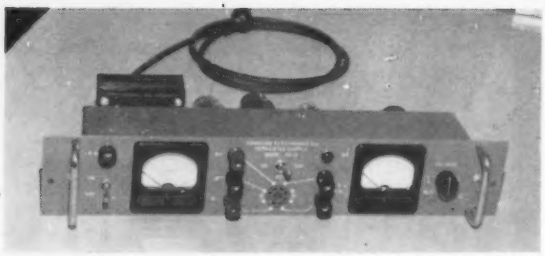
The mechanical design of the unit was based on the need to make the unit compatible with the dynamotor chassis and at the same time rugged and compact. The

Continued on page 26

For much electronic equipment high tension voltage requirements are critical, independence of line voltage and load current fluctuations being very important. Dealing with basic design work, this article shows how maximum voltage stability can be obtained with a minimum amount of circuitry. Stabilization ratio of the final unit is better than 100 at any voltage setting.

P. GOMARD, P.ENG.*

How to design regulated power units



Regulated dc power supply designed on the principles described in this article provides 100 ma at 190-200 volts

Direct current power supplies for most electronic equipment have received increasing attention in the last decade. The characteristics desired in a good dc supply are:

1) The output voltage *(E)* must be constant or nearly constant when the line voltage *(E_l)* changes. The ratio $\frac{\partial E}{\partial E_l}$ is called the stabilization ratio.
2) When the current *(I)* delivered by the supply changes from zero to the specified maximum value, only a small drop in output voltage can be permitted. The ratio $Z_i = -\frac{\partial E}{\partial I}$ is the internal impedance of the supply and it must be low at all frequencies, dc included.
3) The ripple voltage must be small.

These are the main requirements. Additional desirable features are:

4) Adjustable output voltage using a small potentiometer rather than a variable transformer.
5) A "floating" supply to allow grounding of either B+ or B—.
6) A stand-by switch for the B voltage to facilitate work in the laboratory.

A simple way to achieve the main characteristics is to insert a controllable impedance between the line voltage and the load. This impedance can then be made to vary in such a manner that the output voltage remains constant.

The basic problem is illustrated in fig. 1. The load R is connected between two terminals fed by a battery in series with a resistor R_B. Since

$$E = E_B - R_B I$$

the internal resistance

$$R_i = -\frac{\partial E}{\partial I} = R_B \quad \ldots\ldots\ldots\ldots (1)$$

In a simple power supply consisting of a power transformer and a 5V4 tube feeding a capacitor with subsequent filter, the internal resistance is in the order of 1000 ohms. An increase in load current of 20 mA will therefore cause a drop in the output voltage of 20 volts.

Addition of Feedback Amplifier

Fig. 2 shows the addition of a triode as the controllable impedance. The plate current in a triode depends upon the plate voltage *(E_A)* and the grid voltage *(—E)*. That is,

$$I = f(-E, E_A)$$

and its differential is

$$\partial I = \frac{\partial I}{\partial E}\partial E + \frac{\partial I}{\partial E_A}\partial E_A.$$

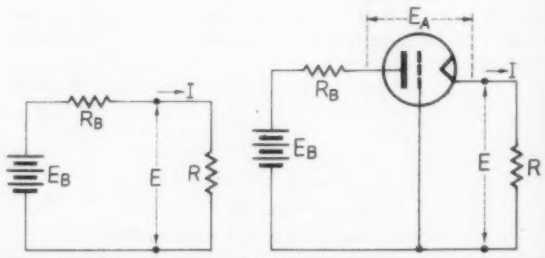


Fig. 1 (left) illustrates the basic problem of internal resistance. Fig. 2 shows triode being used as a controllable impedance to give some improvement in regulation

*Canadian Electronics Co. Hamilton.

Introduction of the tube constants

$$g_m = -\frac{\partial I}{\partial E} \quad \text{and} \quad r_p = \frac{\partial E_A}{\partial I}$$

gives

$$\partial I = -g_m \partial E + \frac{\partial E_A}{r_p} \quad \ldots\ldots\ldots\ldots (2)$$

From fig. 2 it follows that

$$E_A = E_B - E - R_B I \quad \ldots\ldots\ldots\ldots (3)$$

Hence

$$\partial E_A = -\partial E - R_B \partial I \quad \ldots\ldots\ldots\ldots (4)$$

which, when combined with (2), gives

$$\frac{\partial E}{\partial I} = -\frac{1+\frac{R_B}{r_p}}{g_m + \frac{1}{r_p}}.$$

Therefore, according to (1),

$$R_t = \frac{1+\frac{R_B}{r_p}}{g_m + \frac{1}{r_p}} = \frac{r_p}{1+\mu} + \frac{R_B}{1+\mu} \quad \ldots\ldots (5)$$

which is the general expression for the output resistance of a cathode follower.

The original internal resistance R_B from fig. 1 has been reduced by the factor $1+\mu$ but the term $\frac{r_p}{1+\mu}$ has unfortunately been added. If the tube in fig. 2 is a triode-connected 6Y6 (r_p=850 ohms and μ=5.5) and R_B is assumed to be 1000 ohms, then, using (5), R_t=285 ohms.

Some improvement has obviously been gained. The voltage will now drop 5.7 volts instead of 20, but much better results can be obtained by adding more circuitry.

Addition of Second Feedback Loop

In the circuit shown in fig. 3 an amplifier with a gain of $-A$ has been added. A portion $\frac{R_2}{R_1+R_2} E$ of the output voltage is applied to the amplifier. The negative sign indicates a phase reversal of the "error-voltage."

If the voltage applied to the grid is called E_c (in phase opposition to E), (2) can be rewritten

$$\partial I = g_m \partial E_c + \frac{\partial E_A}{r_p} \quad \ldots\ldots\ldots\ldots (6)$$

But

$$E_c = -A \frac{R_2}{R_1+R_2} E,$$

so that

$$\partial I = -g_m A \frac{R_2}{R_1+R_2} \partial E + \frac{\partial E_A}{r_p}.$$

Since (3) and (4) still hold, g_m has apparently been increased by the factor

$$A \frac{R_2}{R_1+R_2}, \text{ so (5) becomes}$$

$$R_t = \frac{1+\frac{R_B}{r_p}}{g_m A \frac{R_2}{R_1+R_2} + \frac{1}{r_p}} \quad \ldots\ldots\ldots\ldots (7)$$

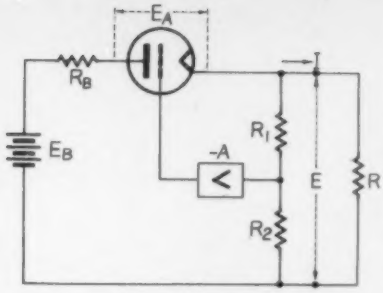


Fig. 3. Addition of amplifier in feedback loop gives further improvement

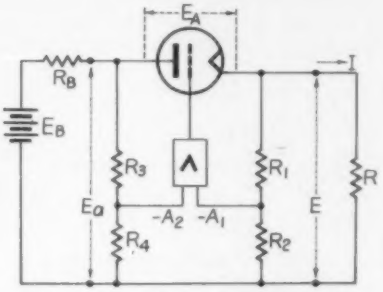


Fig. 4. Dual-input amplifier circuit used in unit shown on opposite page

A decrease of R_t to, for example, 10 ohms will require

$$\frac{1+\frac{1000}{850}}{\frac{5.5}{850} A \frac{R_2}{R_1+R_2} + \frac{1}{850}} = 10$$

giving

$$A \frac{R_2}{R_1+R_2} = 33.5.$$

As it turns out in practice, $\frac{R_2}{R_1+R_2} \sim \frac{1}{2}$, resulting in a required gain A $\sim$ 67.

This is a practical proposition and instruments of better quality will often have built-in power supplies with an internal resistance of approximately 10 ohms. By equipping the amplifier with dual input as shown in fig. 4 a further improvement can be obtained. The voltage fed from the R_1, R_2 divider is the same as that in fig. 3. It is amplified $-A_1$ times.

At the plate of the tube the voltage is

$$E_a = E_B - R_B I$$

and its differential

$$\partial E_a = -R_B \partial I \quad \ldots\ldots\ldots\ldots (8)$$

is obviously proportional to the differential of the load current. The voltage E_a is attenuated by R_3, R_4 and fed to the amplifier, where it is amplified $-A_2$ times. The amplifier can be designed to give an output voltage, the differential of which is

$$\partial E_c = -A_1 \partial\left(\frac{R_2}{R_1+R_2} E\right) - A_2 \partial\left(\frac{R_4}{R_3+R_4} E_a\right) \quad \ldots (9)$$

By combining (8) and (9), we have

$$\partial E_c = -A_1 \frac{R_2}{R_1+R_2} \partial E + A_2 \frac{R_4 R_B}{R_3+R_4} \partial I.$$

Since

$$\partial I = g_m \partial E_c + \frac{\partial E_A}{r_p} \quad \ldots\ldots\ldots (6)$$

$$\partial E_A = -\partial E - R_B \partial I \quad \ldots\ldots\ldots (4)$$

and

$$R_i = -\frac{\partial E}{\partial I} \quad \ldots\ldots\ldots (1)$$

it is easily found that

$$R_i = \frac{1 + \frac{R_B}{r_p} - g_m A_2 \frac{R_4 R_B}{R_3 + R_4}}{\frac{1}{r_p} + g_m A_1 \frac{R_2}{R_1 + R_2}} \quad \ldots\ldots (10)$$

By comparing (10) with (7) it is seen that the effect of the second channel shows up as an added negative term in the numerator. To obtain zero internal resistance

$$A_2 \frac{R_4}{R_3 + R_4} = \frac{1 + \frac{r_p}{R_B}}{\mu} \quad \ldots\ldots\ldots (11)$$

For the numerical case previously mentioned (11) leads to

$$A_2 \frac{R_4}{R_3 + R_4} = 0.347.$$

If the amplifier is a single pentode using the control grid as the A_1 channel and the screen as A_2, it only becomes a question of adjusting R_3 and R_4 since the amplification factor from screen to plate is in the order of 10 or more. Since R_B, μ and r_p may change with the age of the tubes, it is advisable to set the internal impedance to a small positive value such as 0.5 ohms to insure against a negative R_i.

The evaluation of the stabilization ratio can be carried out by using the relationships developed above. The procedure is simple but laborious and only the result for the circuit in fig. 4 is given here:

$$\frac{\partial E}{\partial E_B} = \frac{A_2 \frac{R_4}{R_3 + R_4} - \frac{1}{\mu}}{\frac{R_i}{R_B} \frac{1}{g_m R_B} + \frac{1}{\mu} - \left(A_2 \frac{R_4}{R_3 + R_4} + A_1 \frac{R_i}{R_B} \frac{R_2}{R_1 + R_2} + \frac{R_i}{R_B \mu} \right)} \quad \ldots\ldots\ldots (12)$$

If R_i is set to zero by fulfilling the requirements of (11), the stabilization ratio would be

$$\frac{\partial E}{\partial E_B} = -\frac{\frac{1}{g_m R_B}}{A_1 \frac{R_2}{R_1 + R_2} + \frac{1}{\mu}}.$$

This, however, is not done, as mentioned above. In the practical case where R_i is approximately 0.5 ohms, the stabilization ratio (12) is in the order of 0.01.

General Conclusion

A power supply has been built based on the circuit of fig. 4 but with a capacitor-input power supply substituted for the source battery E_B.

The dual channel amplifier consists of a 6SJ7 with the A_1 signal fed to the control grid and the A_2 signal applied to the screen. The voltage range is 190-250 volts and the maximum load current is 100 ma. The measured internal impedance (see footnote) is around 0.5 ohm and the ripple is less than 10 mv rms. A bridge circuit ensures that the waveshape of the ripple is essentially sinusoidal. The stabilization ratio is better than 100 at any voltage setting.

Further design improvements can be made, but the added circuitry required will add materially to the cost. For supplies of medium rating the approach described above gives a design of optimum performance, weight and cost. END

Footnote: The impedance rises with frequency from the dc value of 0.5 ohm to just under an ohm after which it drops off due to a capacitor shunted across the output terminals. The methods used for the impedance measurements are described in IRE Standard *No. 50 IRE 23, S3.*

Transistors take over — continued from page 23

design had to ensure that a sufficiently good heat sink was provided for the transistors.

COMPARISON TABLE

	Dynamotor	*Transistor Inverter*
Weight	8.25 lbs.	2.2 lbs.
Efficiency	50%	80%
Life without maintenance	1,000 hours	10,000 hours
Shock	30G	100G
Temperature		—55°C to +51°C
Run up time	1 second	immediate

The comparison table shows how the transistor inverter proves a ready substitute for a dynamotor, as the power supply for airborne electronic equipment, where high power is required at h-t from a low voltage dc source. It is well suited for telecommunication equipment where transmit-receive modes of operation require that the equipment operate through a large number of "off-on" cycles. The immediate voltage build-up by this supply removes the problem of dynamotor run-up time which can be of the order of one second to full voltage. END

References: G. H. Royer, "A Switching Transistor DC to AC Converter Having an Output Frequency Proportional to the DC Input Voltage." AIEE Transactions Paper 55-73, 1955.

P. L. Bright, "Junction Transistors Used as Switches." AIEE Transactions Paper 55-156, 1955.

R. L. Van Allen, "A Variable Frequency Magnetic Coupled Multivibrator." AIEE Transactions Paper 55-75, 1955.

G. C. Uchrin and W.O. Taylor, "A New Self-Excited Transistor Power Oscillator." Correspondence in IRE Proceedings Vol. 43, No. 1 p. 99, January, 1955.

Although engineers have long been using quartz crystals for frequency control, few have ever seen them being made. This is a picture tour down the production line.

IAN R. DUTTON, ASSOCIATE EDITOR

Brazilian quartz used in manufacturing radio crystals.

Crystal production is a skilled job

Have you ever tried to figure out the amount of electronic equipment in Canada that relies upon quartz crystals for frequency control? Without trying too hard you can reach a figure that looks like the national budget surplus.

To mention some of the major equipments using crystals, there are broadcast transmitters, communications equipment, microwave equipment, radar, navigational aids, missiles, telephone equipment and test equipment. All represent large investments in engineering design and production, sometimes operating in large systems that involve human safety and additional expensive equipment.

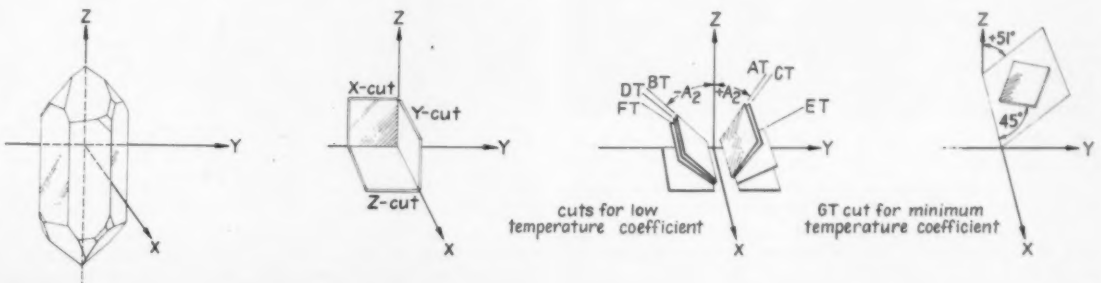
Reliability in all cases is highly desirable—in some it is paramount. There are many vulnerable points in any circuit but the crystal, being the heart, carries a major burden of responsibility. In turn, this responsibility rests upon the shoulders of the people who make them.

Quartz is a common substance, silicon dioxide (SiO_2). About 1/10th of the earth's surface is made up of this material but quartz crystals suitable for piezoelectric vibrators are found in very few places. Brazil is the chief source in the western hemisphere.

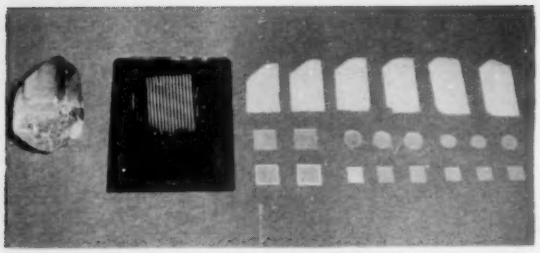
Fortunately for the electronics industry, quartz crystals, when properly processed, are capable of maintaining frequency stability of a very high order. Low-cost crystals can be produced that will, when used in a well-designed oscillator circuit, remain within a drift tolerance of ±0.003% over a temperature range of —55°C to +100°C. By using an inexpensive oven with a temperature differential of ±3°C (currently available for less than $10), this drift can be reduced to ±0.0003%.

To produce crystals of this stability, however, some specialized equipment and techniques are involved. But most important, a group of skilled people is a prerequisite to success. These are the main production steps:

The author is indebted to the C. R. Snelgrove Co. Ltd. for their assistance.

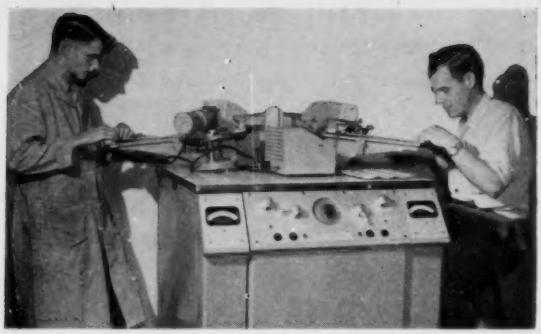


Crystal production



1 Quartz crystals mined in central Brazil are inspected before shipment to ensure that they will be suitable for use as piezoelectric resonators. The manufacturer carries out further tests to determine the orientation of the axes and locate any remaining faults. Several instruments have been developed to do this, some using polarized light, some employing an etching process and some using x-rays. This is an important part of the work since the quality of the finished crystal depends upon the accuracy with which the axes can be established and the cuts made. ($\pm 2'$ is the maximum permissible angular deviation.)

2 Having located the Z (optic) and X (electrical) axes, the operator bonds the quartz to a glass support and fastens it in the holder of the automatic saw. Trial wafers are cut and tested on the x-ray machine to ensure that the angle is correct. With the final adjustments made, the saw is set for automatic operation to complete the sequence of cuts unattended.



3 The wafers are further tested on the x-ray machine to classify them accurately according to the angles at which they were cut.

4 Blanks are cut from the wafers and sorted automatically into groups of approximately the same thickness. Several stages of lapping and checking then bring the blanks down to the correct thickness. Care must be taken to ensure that the sides remain plane parallel and that the finished blanks are free from surface cracks or scratches. Several blanks are lapped at one time, held and guided by a thin plastic or fibre nest between two metal ring laps. The ring laps are electrically insulated and connected to the input of a sensitive receiver. As the lapping progresses, the thickness is checked by tracking the frequency of the crystals in the receiver.

5 Final lapping is done in a high-speed machine designed specifically for this purpose. The blanks are relocated in the nest at intervals to ensure that they are all being ground to the same thickness and that the faces are parallel. The thickness of a 5 mc crystal is approximately 132 microinches and to maintain a frequency tolerance of $\pm 0.003\%$ allows a thickness tolerance of only ± 0.004 microinches.

Thorough cleaning is essential for stable operation of a crystal over long periods. Small residue particles left on the blanks after lapping, or migrating from the support leads or cover, will gradually alter the frequency. This may be as much as 0.02%, in contrast with frequency

change of one part in 10^7 for normal ageing. Dirt can also weaken the bond between the electrodes and the crystal faces.

A step-by-step look at the highly-skilled craftsmanship involved in producing crystals for electronics

6 The silver electrodes are deposited on the sides of the blanks by vapor diffusion in a vacuum chamber. A mask (arrow) holds the blanks and controls the shape of the deposit.

7 The blank is now mounted in its holder. At this stage the frequency is several kc above the final frequency and must be adjusted. The crystal is oscillated under vacuum and a small additional amount of silver is deposited on the crystal until it zero beats with a standard crystal which has been accurately set on the desired frequency.

8 The blank is cemented into its holder and placed in an oven to cure the cement and normalize the crystal. Further electrical tests ensure that the crystal will oscillate with the required activity at the specified frequency. The metal cover is then soldered in place and several crystals are loaded into a chamber that is first evacuated, then filled with nitrogen. While in this, the vent holes in the covers are sealed with solder.

The final step is another rigid inspection. Careful workmanship, cleanliness and repeated inspections are the real guarantees for reliable crystal operation, not only as they leave the plant, but for many years — provided they are used correctly.

END

Dr. W. V. TILSTON & C. M. SPENCER*

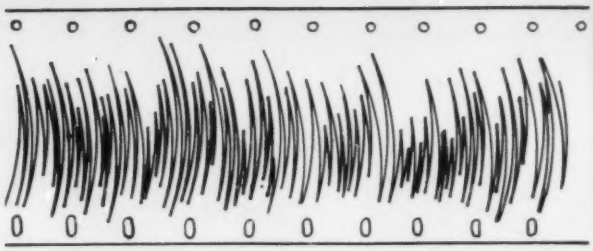


Fig. 1. Sample section from an amplitude-time type of strip chart

Unit will analyze chart records

The automatic chart analyzer described in this article was designed and built for the Radio Physics Laboratory of the Defence Research Board of Canada, for the purpose of analyzing the amplitude distribution of a fluctuating radio signal which has previously been recorded on an Esterline-Angus paper chart.

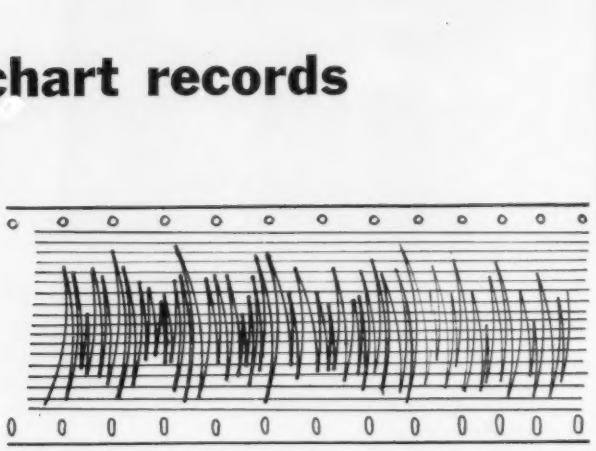


Fig. 2. Same section of chart with 17 amplitude sections added

One of the main reasons for keeping chart records of a particular function is so that statistical data may be derived about its behavior. For instance, in the case of a temperature record, it may be desirable to know such things as the average temperature over a period, the maximum temperature, and the minimum temperature.

The statistical data obtained in these processes may be used to check past performance and to predict future performance.

In the case under consideration, the amplitude of the received radio signal actuates a pen drive which in turn marks an Esterline-Angus strip paper chart. This chart is continuously moving past the pen which moves in a circular arc whose radius depends on the chart width. Thus, a rectangular plot of signal strength against time is not obtained, since the time axis is a straight line, and the amplitude axis is a circular arc. A sketch of a sample recording is shown in figure 1.

Seventeen Channels

If the amplitude axis is so divided that seventeen equally spaced amplitude regions, or channels, result, then it is desired to know what percentage of the time the received signal was as great as or greater than each amplitude level, in a given time interval.

A manual analysis of a section of chart may be carried out in the following manner:

The chart in question may be already ruled or it may be unruled. If it is ruled, there will be equally spaced horizontal lines whose separations represent equal amplitude increments, and equally spaced circular arcs whose separations represent equal time intervals. The centre of the circular arcs will be on the centre line of the chart.

If the chart is unruled, then these lines could either be ruled on the chart, or on a clear plastic sheet which was placed over the chart.

A section of such a chart showing seventeen amplitude sections is shown in fig. 2.

The chart is examined between the two circular arcs required. For each amplitude region, the number of times the signal line crosses all the circular arcs in that region is recorded. It can be seen that, for a given region, the total number of crossings is proportional to the time spent by the signal line in that region. The accuracy of this method of course, depends on how closely the circular arcs are spaced and on the type of signal curve being analyzed.

A further calculation is required on the information already obtained, in order to tell the amount of time that the signal was above this level. This merely amounts to an accumulative count.

The above method is only one way of manually analyzing a chart but will serve to compare manual methods with the automatic method.

Visual to Electrical

In the manual method of analysis then, the signal is first turned into visual information on a chart, and visual means are used for making the necessary measurements.

Since the automatic chart analyzer is an electronic device, the first problem is to turn the visual signal information on the chart back to electrical information.

This is done by scanning a section of the chart with a

*Sinclair Radio Laboratories Ltd., Toronto

vidicon. The output of the vidicon then contains the desired electrical information which can be operated upon by the remaining electronic devices to produce the required result, and to display it on electronic counters.

The chart moves along a viewing table at speeds of either four or twelve inches per minute. While it is moving along, the chart can be edited by depressing a push-button which causes a pen to place a black stroke along the edge of the chart.

In the present model, the part of the chart containing the black line is not analyzed.

Near the end of the viewing table, the chart passes under an opaque plastic rectangular mask in which a viewing slit has been cut. This slit coincides with the curved amplitude axis of the chart.

The vidicon is situated above this mask and views the mask and the slit, fig. 3. Information, in the form of electrical impulses, leaves the vidicon whenever the signal trace on the chart is scanned through the slit in the mask.

The horizontal scan moves lengthwise over the mask in the same direction as the time axis on the chart at a frequency of 15,750 cycles per second. The vertical scan moves across the chart at right angles to the time axis at a frequency of 60 cycles per second.

This means that the slit is viewed along its arc length at 262.5 places each 0.016 of a second.

Time of vidicon pulses

It should be noted that while the voltage of the original electrical signal, which moved the recording pen, varied in amplitude, the information output from the vidicon consists of pulses whose voltage is approximately constant. It is the time at which the pulses occur during a vertical scan that determines to what amplitude section of the chart they correspond. This being the case, it is clear that one way to separate out the video information into seventeen channels, corresponding to seventeen amplitude sections of the chart, is to switch the vidicon output to each of seventeen separate stages consecutively, at evenly spaced intervals, while the vertical scan is traversing the chart. In order to accomplish this, switching and gating tubes are used.

In all, there are seventeen gates whose inputs are connected in parallel. The information from the vidicon, after passing through suitable shaping and scaling circuits, is fed to the input of the parallel gates. These gates are normally closed so that no information can pass through them. Switching tubes open these gates consecutively. In this manner, while the vidicon is scanning region number one, only gate number one is open and so on with the other regions.

Thus, information from each region is switched to its corresponding gate output, and hence, to the electronic counters which represent the region in question.

If nothing else were added at this point, then the counters associated with each amplitude region of the chart would indicate the amount of time the graph was in that region.

In order that the counters associated with one region shall indicate the amount of time that the graph was either in that region or in other regions representing greater amplitudes, diode circuits are used to transfer a particular counter input to all lower counters in the chain.

It should be noted here that the amount of chart that can be examined at one time will depend upon the chart speed, the scaling factor used, number of counters allowed per channel, and the accuracy required.

The present model offers a choice of two chart speeds, a slow speed of four inches per minute, and a fast speed of twelve inches per minute.

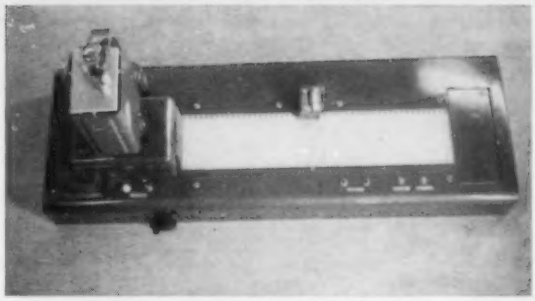


Fig. 3. The chart drive chassis mounts the vidicon readout camera at the left and the manual editing device, centre.

An editing device marks the parts of the chart which are to be analyzed.

The counter values when plotted give the distribution curve.

Three amplifying stages

The camera used to read the information from the chart employs a 6198 vidicon tube. There are three stages of video amplification in the camera unit itself. The video output from the camera is in the neighborhood of 0.10 volts. The video amplifier following the camera unit has a gain of about seventy and also contains differentiating circuits to sharpen the video pulses.

The signal from the video amplifier is fed into a clipper stage. This stage clips the large horizontal blanking pulses, which are superimposed on the signal, so that they are equal in amplitude to the information pulses. If this were not done, the blanking pulses would ride through the next gating circuit, unless a much greater bias was used. This would cause a much greater gating voltage, which is undesirable. The clipper is followed by a gating circuit which passes and amplifies the information pulses, and cuts out all of the horizontal blanking pulses. This gate also cuts out any information from outside a narrow section on each side of the viewing slit, thus blocking any stray signals from the edges of the mask. The gate control is formed by taking the horizontal line frequency from the camera control and squaring it.

Since the information pulses vary with the width and density of the line, the signal from the gated amplifier is fed to a monostable flipflop, which gives out one pulse for every input pulse, the output pulses being constant in shape and amplitude.

From the monostable flipflop, the signal is fed into another gated amplifier which scales the number of pulses.

Scanning time

The width of this gate is adjusted to eliminate any vertical blanking pulses from the signal. The frequency of these gating pulses effectively controls the number of times the chart is scanned in a second. This in turn depends on the nature of the graph, the number of counters used in the final output for each channel, and the length of chart to be analyzed. A phantastron circuit, accurately controls the gate width so that all the information from the chart will come through but the vertically blanking pulses are stopped. The width of this gating pulse is more critical than that which eliminates horizontal blanking pulses, since in the latter case the information from the slit is coming from a fairly narrow portion near the centre of the horizontal scan.

At this point the information pulses are positive and have the proper shape for feeding the channel gates (or amplitude section gates). The inputs to these channel gates are in parallel and require a signal from a low-impedance

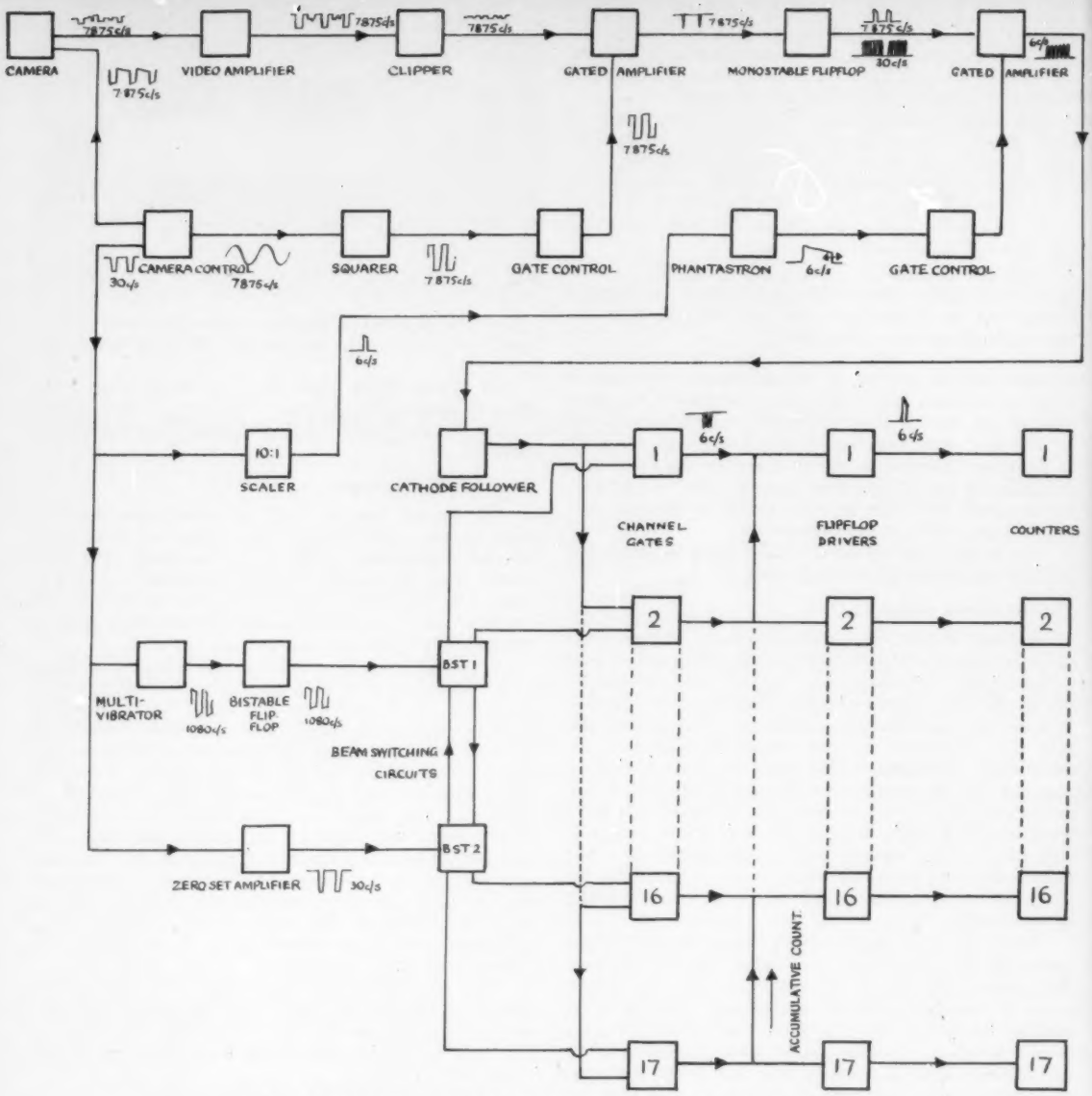


Fig. 4. Block diagram of the Sinclair Automatic Chart Analyzer.

source. For this reason, the information pulses are fed through a cathode follower before they enter the common input to the channel gates.

The channel gates are normally closed. They are opened in succession by beam switching tubes as the vidicon scans vertically through each channel or amplitude section of the curved viewing slit in the mask which covers the chart.

The beam switching tubes are driven from a multivibrator which is synchronized to the vertical sweep frequency, so as to give pulses whose width corresponds to the time taken by the vidicon to sweep over one amplitude section of the chart. Thus, the output from each gate represents a particular amplitude section of the chart and the number of pulses appearing at each output represents the number of times the signal was in that amplitude section.

Each channel gate is fed to its respective flipflop driver, which serves two puprposes. First, it provides the necessary pulse shape for feeding the electronic counters. Secondly, its time constant is such that only one pulse may proceed to the counters from a particular channel during one vertical sweep.

In order that the counters for one channel shall indicate the amount of time that the signal was either in the corresponding amplitude section or in one of higher amplitude, an accumulative count is introduced at the inputs to the flipflop drivers. This takes the form of a chain of diodes connectiong the driver inputs, so that the signal to one driver feeds all preceding drivers in the chain. The driver outputs feed electronic counters, which indicate the accumulative count.

While the information in this instance was fed to electronic counters in the form of an accumulative count, it could of course be processed by additional circuits to give other statistical information which might be required for a particular application. In addition, the instrument could also be modified to work with other types of charts. END

Regulating systems use feedback control to obtain stabilized operation. The feedback principle has wide applications, particularly in industry where it can control heavy rolling mills or nylon thread spinning machines. This article deals with the theory of feedback, both positive and negative, and describes how it is used in industrial drives.

C. G. HELMICK*

Feedback control principles

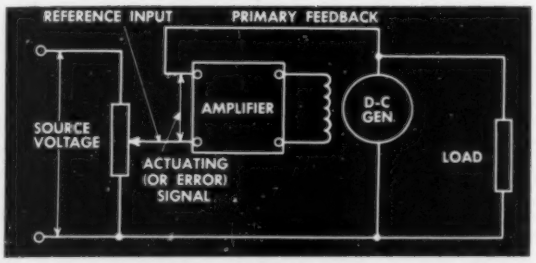


Fig. 1a. Feedback control applied to an electric regulated system for holding the voltage of the generator constant

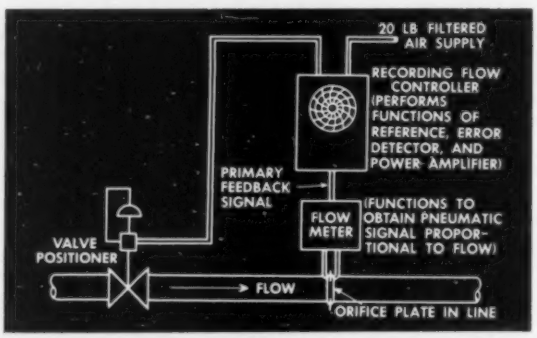

20 LB FILTERED AIR SUPPLY
RECORDING FLOW CONTROLLER (PERFORMS FUNCTIONS OF REFERENCE, ERROR DETECTOR, AND POWER AMPLIFIER)
PRIMARY FEEDBACK SIGNAL
FLOW METER
(FUNCTIONS TO OBTAIN PNEUMATIC SIGNAL PROPORTIONAL TO FLOW)
VALVE POSITIONER
FLOW
ORIFICE PLATE IN LINE

Fig. 1b. A pneumatic regulated system using feedback control for holding constant flow rate in a pipe line

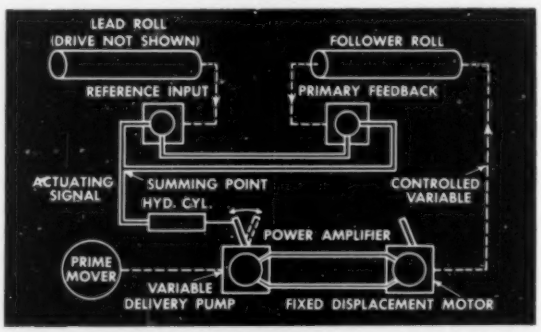


Fig. 1c. The speed of two mill rolls can be matched by a hydraulic regulated drive system using feedback control

The hiss and roar of a giant, white-hot ingot being rolled in a blooming mill is ample testimony to the tremendous power harnessed to this task; in contrast, the contented purr of a machine spinning delicate man-made fibres attests to the gentle action with which this process is controlled. Behind this dramatic contrast is a basic and fundamental similarity; both are examples of the same principles of feedback control.

In any feedback regulator system, the output quantity to be regulated is compared to an input reference, which is proportional to the desired output, and the difference is kept as small as possible — ideally zero. This is accomplished by measuring both input and output, comparing them, and using the difference to control the output. The system components can be electrical, hydraulic, mechanical, pneumatic, or any combination of these. In addition, modern process control makes use of any number of transducers, devices that convert some process variable to a control signal for regulating purposes. Although the individual blocks in a diagram can assume an infinite number of physical forms, their function in a feedback control system follows similar principles.

Industrial drives

Industrial drives utilize the same principles as other regulating systems, but have some special requirements of their own. The power level involved usually sets the industrial drive clearly apart from its counterpart—the instrument drive. A positioning servo for an analog computer, or a self-balancing protentiometer for recording instruments uses low-power components of special design to get characteristics tailored to the application. On the other hand, the power ratings of most industrial drives are so large that design of these machines for ideal control characteristics is impractical. For example, a 50-hp squirrel-cage servomotor designed with linear control characteristics would have to be prohibitively large to dissipate the high resulting rotor losses. Economic factors must also be considered; a servomotor with an efficiency of 10 per cent may be entirely practical for a sub-fractional-horsepower instrument drive, but could hardly be considered for 100-hp screw-down motors on a rolling mill.

Hence, special features of small drive components can seldom be duplicated at industrial power levels. As a compromise, near-standard machines are used where possible, and the feed-back controller recovers the attendant loss in performance. Fortunately, this usually can be accomplished, but not without a thorough examination of the entire system. For high-performance systems, standard

*Westinghouse Electric Corporation, East Pittsburgh, Pa.

Block diagram shows why the feedback cycle keeps control

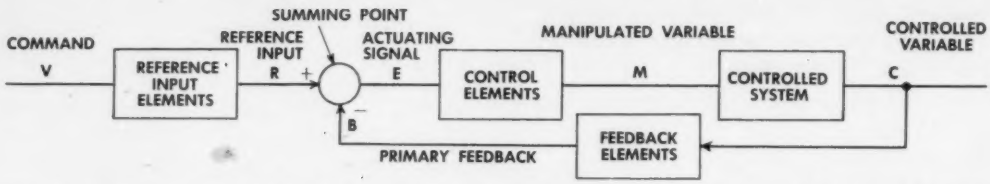


Fig. 2. Basic components in any feedback control system are shown in this simplified block diagram

elements may have to be modified to reduce time delays, improve machine gains, or reduce saturation effects. From a cost standpoint this is nearly always less expensive than designing a new machine with special characteristics. The ultimate consideration is drive performance, and if this can be met with conventional equipment, it is the practical solution.

Performance

From the operating viewpoint, performance is the most important single factor. Will the mill roll acceptable products with a given drive? Does a production run of nylon yarn have sufficiently uniform denier to permit successful dyeing? If not, what adjustments must be made.

In general, the quality of performance of a regulated system can be described by three factors: (1) steady-state accuracy, (2) system speed of response, and (3) system damping, or rate of decay of oscillations. The first term describes how closely the controlled variable normally can be held in relation to the command input, which is certainly an important consideration; speed-of-response describes how *fast* normal conditions can be restored to a system after a disturbance; and system damping describes the manner or *quality* with which normal conditions are restored after the disturbance. Actually, all three performance factors are closely interrelated.

Steady-state accuracy

The normal accuracy with which system output follows the command input signal depends upon *system amplification*. Technically speaking, this is the open-loop amplification or gain, which can be found in a simple system by taking the product of the gains of all components in the loop, including the feedback loop. The term "open-loop" derives from the fact that if the control loop is opened at any point, the system amplification can be found by inserting a test signal at one point of the break and measuring the signal that results at the other side of the break. The ratio of these two signals is the system (or open-loop) amplification.

For more complex systems with minor loops, parallel elements, feed-forward loops, etc., methods are available to reduce such systems to an equivalent series block diagram. The product of the gains of the simplified components so obtained is system amplification.

Adjustment for system amplification is most readily made by adjusting amplifier gain. In practical industrial systems, gains of exciters, generators, or tachometers are relatively inflexible once designed. Consequently, the amplifier is provided with excessive gain, so that a simple adjustment of an input-sensitivity potentiometer produces the desired system gain.

While open-loop gain is the quantity most easily adjusted, certain feedback methods can increase or decrease the effect on performance. While the loop remains open, amplification is normally high, say 10 to 500. As soon as the loop is closed, however, the "through-gain" or "closed-loop" gain can be shown to approach unity, as indicated by the equation:

$$\frac{\text{Output (per unit)}}{\text{Input (per unit)}} = \frac{C}{R} = \frac{A}{1+A} \qquad (1)$$

The desired value of C/R, which is the ratio of output to input (both expressed in per-unit quantities), will be close to unity since normally the purpose of the regulator is to provide a one-to-one relationship. A large value of open-loop gain A will cause C/R to approach unity. Steady-state error is based upon this idea, by measuring how much error exists between C/R and unity. Hence:

$$\begin{aligned} \text{Error} &= 1 - \frac{C}{R} \\ &= 1 - \frac{A}{1+A} \\ &= \frac{1}{1+A} \end{aligned} \qquad (2)$$

A steady-state error always exists unless amplification can be made infinitely large. This error is the necessary actuating signal to run the system from no-load to full-load output. Some systems, however, utilize *positive* feed-

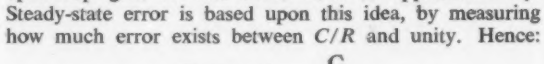


Fig. 3. Typical system response to a step-input disturbance

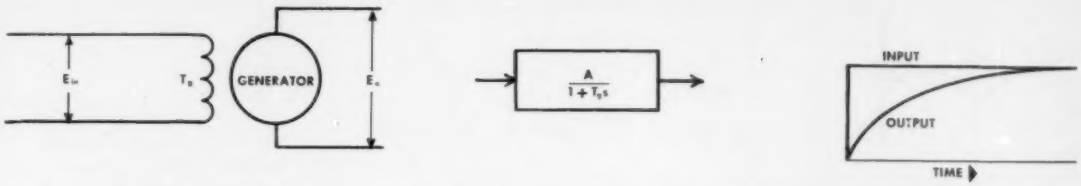


Fig. 4a. Effect of time delays on a simple single-delay system, such as a dc generator, that has no feedback

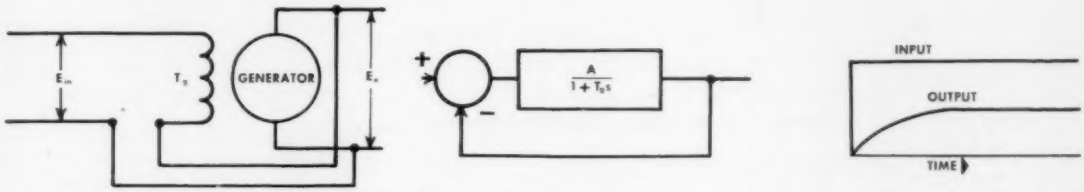


Fig. 4b. The single-delay system but with feedback. For example: dc generator with negative feedback to generator field

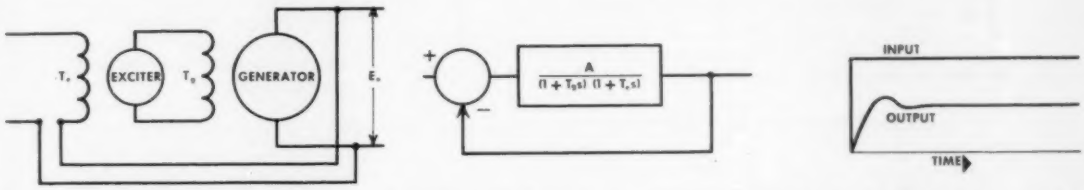


Fig. 4c. A two-delay system with feedback. This might be a dc generator with negative feedback to the excitor field

back, or self-energization, to achieve the same effect as infinite steady-state gain. These systems actually operate with negligible steady-state error. While the steady-state gain is made very large by the use of self-energization, this has little or no effect on the gain during transients. More will be said about this later.

Speed of response

System performance consists of more than the steady-state condition. A system is subjected to various disturbances from time to time, and must return to normal operation rapidly and effectively. These disturbances can be caused by load changes, power-supply variations, changing machine characteristics, ambient conditions, or many other factors.

The most widely used method of measuring response to disturbances is to apply a step change to the system and observe the output variation. Such a test is relatively easy to perform and represents a much more severe disturbance than the drive is likely to encounter in service. Good response under these worst conditions assures adequate field performance.

Discussion of response time in an exact quantitative manner is difficult because of the many aspects of system response to consider. Several significant aspects of transient response include: (1) time required to first reach a specific percentage of the final value; (2) time required to reach the first peak overshoot; and (3) time required for the transient to decay to a specific value. The most useful approach, short of drawing the response curve, is to speak qualitatively. Thus, in fig. 3, curve 1 has a faster response than curve 2. In the adjustment of a regulating system, the fastest response practicable is usually desirable, but again, this is a relative concept.

The speed of response of any system usually depends on three factors: system amplification, the time delays of the elements comprising the system, and the nature of the disturbance to which the system responds. These factors are interrelated closely. For example, system output will follow input more closely for a slow moving change than for a sudden change. This was the reason mentioned previously for using a step change as a good field test for over-all performance. Also, other things being equal, a system with a large delay will have a slower response than one with a small delay.

The control designer relates these factors by a block diagram (see fig. 4) containing the terms A, T, and S. The value of A is a constant and is the steady-state value of open-loop amplification previously discussed. T is also a constant, and is the time delay of the element involved.

Feedback: Equivalent representation for negative and positive circuits

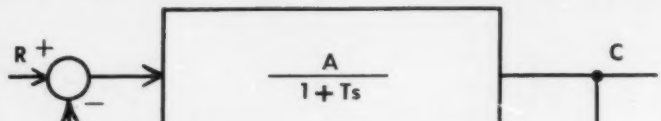
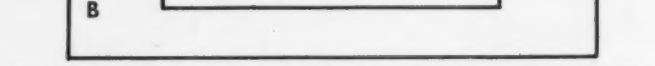


Fig. 5a Above: negative feedback; below: equivalent representation



A=amplification of system, T=time delay, s=Laplace operator

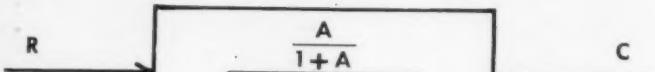


Fig. 5b Above: positive feedback; below: equivalent representation

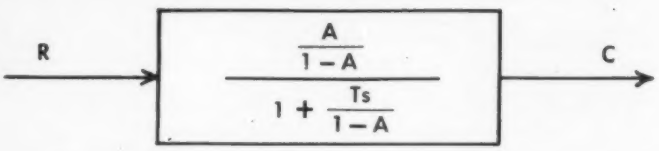


Fig. 5. The primary feedback signal in a closed-loop system (a) is negative, in that it opposes the reference signal. The effect on system performance is two-fold, since both gain and time delay are reduced. Open-loop amplification A is reduced to A/(1 + A), or approximately unity; main time delay is reduced by the factor 1/(A + 1). Generally, negative feedback reduces gain, but improves stability by reducing the effective main time delay.

Positive feedback, such as self-energization, has an opposite effect. System gain and effective time delay are both increased. This is seen from the equations for the equivalent circuit in (b). As A approaches unity, time delay T approaches infinity. Thus the self-energizing response is sluggish, and has little effect during transients.

S is a variable quantity (the LaPlace operator), which includes the effect of the disturbance function. For a sudden step change, S is very large. For steady state, or no change, S = 0.

Without going into the mathematical analysis of feedback control systems, a high speed of response generally requires high amplification. A maximum permissible value of gain exists, however, above which the system will be unstable. A practical method of installation adjustment is to increase the gain as much as possible while still avoiding a hunting or oscillating condition. This value of gain is then reduced by a small amount to provide a margin for stable operation.

The oscillating condition results from the interaction of the component time delays when system gain becomes too high for stable operation. In all but the simplest cases, this inter-relation is not obvious, and few generalizations can be made. In a simple single-delay system, response time is proportional to the single time delay involved. Any faster response time is achieved by reducing the effect of the single time delay. This can be done by increasing the system gain, reducing the time delay directly, or by forcing (discussed later). For example, if the delay is an electrical field delay expressed by T = L/R, it can be reduced directly by increasing the resistance, R. However, the applied voltage must be increased to overcome the added resistance drop. A practical solution often used is to reconnect a 230-volt field into two parallel 115-volt fields, with sufficient external resistance to operate from the 230-volt fields, with sufficient external resistance to operate from the 230-volt supply.

For two-delay systems, the generalized response is shown in fig. 6 for different values of system damping. Note that in all cases the time to reach the peak overshoot appears to be about 3 or 4 times the natural period expressed as *response time*. Response time can be improved by increasing system gain, but this also results in less damping and greater overshooting. Although a generalized response can be made for two-delay systems, most practical regulating systems involve a higher number of delay elements, thereby making the analysis more difficult. Some generalization can be made for the higher order systems; for example, time delays should be a widely separated as possible. In doing this, reduction of the small delay will usually be more effective than increasing a large delay.

Response time has little significance unless system damping is also considered. Damping from the performance standpoint describes the *quality* of response; in other words, how much oscillation takes place, and how fast does it disappear? System damping is often measured in

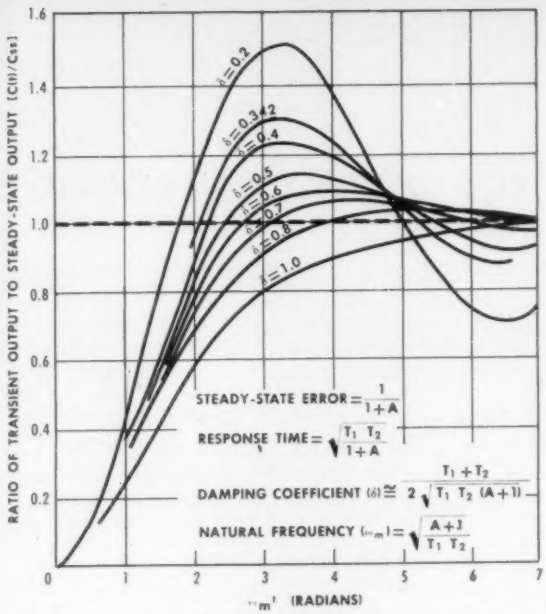


Fig. 6. Response of two-delay feedback control system

terms of "per cent decay per cycle." This figure is helpful since it evaluates the effect of damping regardless of response time. It is not sufficient to speak of decay *time* alone, because such a term could be the same for a fast system or a slow system, whereas the effective damping may be much different.

In many industrial systems some overshooting is entirely satisfactory as long as the peak overshoot and settling-out time are not excessive. A paper-machine reel drive, for example, may need only 80 per cent damping, since slight oscillation will not alter the quality of the paper. On the other hand, at the wet end of the machine where the paper is formed, oscillations can produce variations in the paper thickness. Here, system damping may have to be 95 or 100 per cent per cycle.

To understand the factors that influence system damping, its basic nature must be considered. In the fundamental system previously considered, the feedback controller sees only the relation between input and output signals. If the corrective action is proportional only to the difference of input and output, the system will probably overshoot the mark in responding to a disturbance. This is particularly true for systems with high inertia, where accelerating and decelerating torques can be as great or greater than the load torque. When such a system accelerates toward a new reference point, there is no signal to slow down until overshoot has already occurred.

Rate damping or anti-hunt

If the error signal is modified by a second signal proportional to output *rate of change*, overshooting can be reduced or virtually eliminated. The rate signal is subtracted from the normal error signal, with the net difference used to effect the corrective action. Then with a large difference between input and output, the normal error signal is large compared to the rate signal, and normal corrective action ensues. As the system first accelerates toward the desired operating point, the error signal decreases, and the rate signal increases. Thus the rate signal reduces the corrective effort even before overshoot occurs. In an ideal system, both normal error signal and rate signal disappear as the desired value is attained, and no overshoot occurs. In a practical system such performance can be closely attained.

This type of damping is termed *rate* damping, since it depends on modifying the normal error signal with a signal proportional to the rate of change of the output signal. the terms *damping, anti-hunt,* and *feedback* are often applied to the same fundamental concept of opposing the main actuating signal with another to caution that the system is moving too fast. Sometimes damping circuits are confined to components within the system, such as a two-stage amplifier with inter-stage rate feedback opposing the main signal. In this case, rate feedback tends to stabilize the amplifier. Other examples include feedback rate signals of generator voltage or motor current to indicate that some limiting portion of the system is changing too fast for safe and stable operation. The type and location of these rate circuits is an important part of system design.

A rate signal can be obtained in several ways. A tachometer generator produces a signal voltage proportional to the rate of change of shaft angle. A damping transformer produces a secondary voltage proportional to the rate of change of primary voltage. Resistance-capacitor differentiator circuits produce an output voltage very nearly proportional to the rate of change of the input voltage. These are several electrical methods of obtaining damping. Mechanical damping is also possible by the use of eddy-current devices coupled to the drive motor shaft. Such a device produces a counter-torque proportional to speed. While this method is often used for instrument servos, it is seldom practical for industrial drives. The power that must be dissipated is much greater than for the instrument drive, and the main drive motor must be larger to overcome this loss.

Many simple systems have sufficient damping inherent in the machines to provide stable operation without resorting to special damping circuits. More complicated systems and high gain systems need damping because, in general, high gain tends to make a system less stable. Systems requiring exceptional transient performance must be well stabilized since heavy forcing is usually employed to get fast response.

The object of field forcing is to obtain very fast transient response by minimizing the effects of normal time delays. This is accomplished by calling for a transient output that is higher than needed for the ultimate steady-state condition. If, for example, normal field voltage is applied to a d-c generator, the generator field current and output voltage rise on a simple exponential curve determined by the field time constant. If double the normal field voltage is applied, the field current builds up toward twice normal, according to the same time constant. Consequently, field current reaches its rated value much

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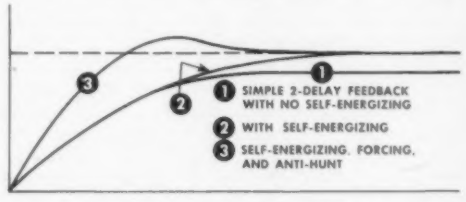


Fig. 7. These typical response curves show the effect of self-energization, which improves steady-state performance, forcing and anti-hunt, and, in turn, the transient performance.

Machine tool men hear of new semiconductor device and versatile logic block

HAROLD PRICE, EDITOR

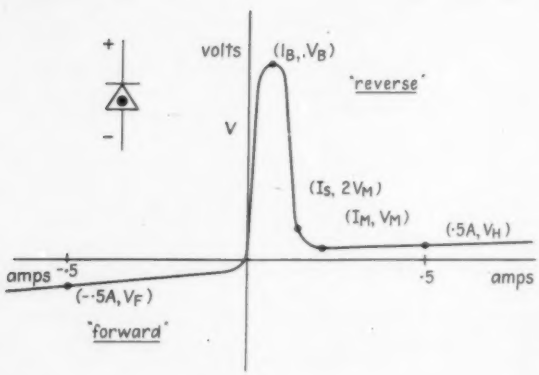
Diode switches in tenth of microsecond

One of the latest additions to the growing field of "neuter" materials—neither all insulator nor all conductor —which have been developed in recent years is the Westinghouse Dynistor diode.

This diode, which appears to offer some outstanding potential applications in power control, was described by A. P. Kruper of WEC's Semiconductor Department at the 21st annual Machine Tool Electrification Forum in Buffalo.

The forum, sponsored by the Westinghouse Electric Corporation was attended by over 300 who learned of two new electronic control devices which open up new possibilities for automation.

The electrical characteristics of the Dynistor diode are shown below; certain regions of the curve have been exaggerated for clarity. The new device resembles any other diode in that it has a forward and a reverse characteristic, in fact the forward characteristic is not unlike the form one would observe for a conventional diode. However, in the reverse direction the Dynistor diode has two distinctly different regions.



Unique reverse characteristic

The first region again resembles a conventional diode. Starting at zero voltage the saturation current increases very slightly with increasing voltage. The second region begins where the device will no longer support voltage, but breaks down to a very low-value voltage. This second region is composed of two parts, a negative resistance region and a hyperconductive region. The hyperconductive region is characterized by a very low resistance value, much lower than in the forward conduction direction.

The specific points of interest on the characteristic curve have been identified by letter symbols which are defined in the table. Associated with each symbol is a representative value or spread of values obtained on germanium Dynistor diodes.

Actual power ratings on these devices have not yet been established, but units have been operated with continuous currents up to 4 amperes and in special applications up to 11 amperes. Under pulsed conditions the units have passed 500 amperes in 5 microsecond pulses. All of the values given in the table are representative of one particular size device and its inventors claim that they are not in any way limits as to what can be done.

Parameter	Definition	Typical Value or Spread of Values
V_B	Peak voltage ("breakdown voltage")	30-150 volts
I_B	Current at peak voltage ("breakdown current")	10 ma
I_S	Minimum sustaining current (defined at $2V_M$)	10-150 ma
V_M	Minimum voltage	.5 volt
I_M	Current at minimum voltage	100 ma
V_H	Hyperconductive drop (at .5 ampere)	.5 volt
V_F	Forward drop (at —.5 ampere)	1.5-5.0 volts
R_H	Average slope of curve between V_M and V_H	.3 ohm
R_F	Slope of curve at (—.5, V_F)	2.0 ohms

One of the most interesting properties of this device, which is not apparent from the characteristic curve, is the switching time in going from a blocking condition to a conducting condition. This breakdown or turn-on time is less than .1 microsecond, while the recovery or turn-off time is of the order of a microsecond. The turn-off time to a certain extent depends on the magnitude of the "on" current and also the circuit configuration.

Triggering

The normal operation of the Dynistor diode is in the reverse or blocking direction. As long as the voltage across it is less than the breakdown voltage, the device will block voltage and be in the "off" condition. If a voltage in excess of the breakdown value is momentarily applied, the operating point will be shifted to a low-voltage, high-current point in the hyperconductive region, and the device will be in the "on" condition.

Another way of triggering is to provide a short duration voltage pulse that is greater than the breakdown voltage. Since the device breaks down in less than a tenth of a microsecond, the triggering pulse duration need only be of the order of a microsecond to ensure positive breakdown. Short-duration, high-voltage pulses suitable for this purpose are readily obtained from simple circuitry using another Dynistor diode.

It is also possible to switch from the blocking to the hyperconductive state by several other techniques, such as: providing a window in the housing of the device so that

light or radiation can be directed into it; or by actually attaching a third terminal to the device in fabrication. The latter configuration is then a three-terminal solid-state thyratron device.

It is clear that this new semiconductor device holds great promise for simplifying many industrial control applications. Although the details presented at the Forum were on a germanium device, which has the temperature limitations inherent in all germanium semiconductors, silicon Dynistor diodes offer promise of higher temperature operation.

The Transistor NOR as a Logic Block

Introducing the second control device, George H. Royer, Senior Engineer in the Director Systems Department of Westinghouse Electric Corporation, Pittsburgh, observed that applications of transistors continue to increase in scope and number. It was the purpose of his talk to outline experience with one such circuit, the transistor NOR circuit, and to present some of its characteristics as a logic element.

The control techniques considered are digital in nature; that is, any output may have only a few finite states depending on the input states. Usually the output is even more restricted in that it will have only two states, ON and OFF. Accordingly, any control device will be either ON or OFF depending on the conditions of the input and the characteristic of the device. Such ON-OFF operation immediately suggests the use of a transistor as a controlled switch.

One of the earliest presentations on this mode of operation was made before the Machine Tool Electrification Forum in 1954 by Dr. R. L. Bright of Westinghouse. The transistor characteristics as they apply to this mode of operation are as follows. The fused or alloy junction transistor when connected in the common emitter configuration, fig. 1, has the collector characteristic shown in fig. 2.

Two stable states

The base current in the transistor is the control which determines which line of a family of curves is the operating line. When used as a switch, only the two extremes of the family are desired. A high base current (300 microamperes for this example) causes operation in the saturation region where the voltage drop across the closed switch is only about 0.2 volts. A small positive base bias voltage insures operation along the low leakage cutoff, or switch open, line.

These two distinct states of the transistor switch are utilized in digital logic elements for which only two-state operation is desirable — a conductive state, when a signal exists at the input, and a nonconductive state, when no input signal is present. Many different systems of logic blocks have been constructed to afford these two states.

All these logic systems are built out of basic logic blocks which are known as the English logic elements: AND, OR, and NOT, as well as Memory or a flip-flop, and Time Delays. The transistor was fitted into these blocks to perform the desired function, but no attempt was made to fully exploit the switching properties of the transistor and to fit the system logic blocks around the transistor.

The transistor switch in the common emitter configuration discussed offers very reliable operation. Its current gain can be utilized so that several input circuits may be connected to each output; thus the use of interstage amplifiers can be avoided. When there is an input voltage to the circuit shown in fig. 3, current flows in the base of the transistor, the emitter-to-collector voltage is almost zero, and there is no output from the transistor; when there is

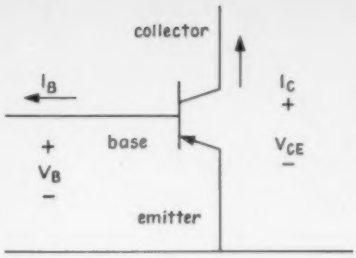


Fig. 1. Junction transistor in common emitter configuration, showing parameters plotted in Fig. 2

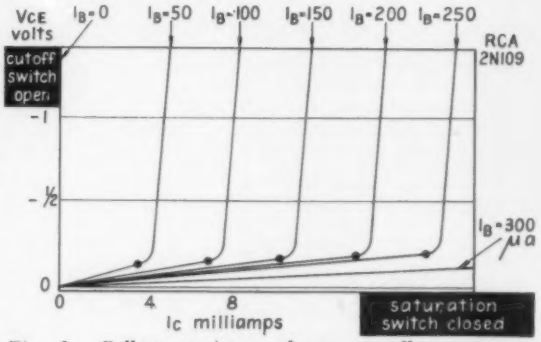


Fig. 2. Collector-emitter voltage vs collector current

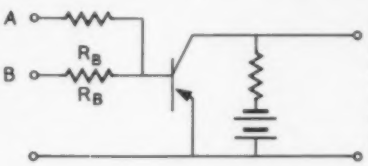


Fig. 3. Basic-circuit of transistor NOR logic block with common emitter configuration

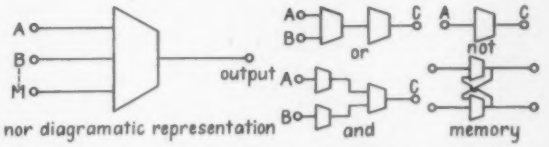


Fig. 4. NOR units combine to form English logic blocks

no input voltage, the transistor is cut off, and the supply voltage appears at the output terminal in series with the load resistor. Thus basically the transistor is a NOT element, an input produces no output, and no input produces an output.

Although this is a logic element, yet in itself it is not sufficiently powerful; to be really useful, a logic element must have at least two inputs to make a decision. If an additional input is added to the base of the transistor so that either input current is sufficient to cause the output voltage to drop to zero, then the output voltage of the transistor will be zero if either A or B has an input voltage. By designating the presence of a voltage signal at an input or an output by a one, and assigning a zero to the no-voltage conditions, the behavior of this circuit can be expressed by the following "truth table":

The output is one if neither A nor B is one
The output is zero if A is one
The output is zero if B is one
The output is zero if A and B are one

The key sentence describing this operation is the first sentence and the key word is the conjunction NOR. Since the output is one only if neither A **nor** B is one, this fact is the basis for derivation of the name "NOR" Circuit.

Several examples are shown of the formulation of the more familiar English logic blocks from the universal NOR block in fig. 4. Two NOR blocks are used to construct the English logic block OR. Three NOR blocks are needed to construct the English logic block AND. One NOR block will also form a NOT block, using only one of the inputs. A memory or flip-flop is formed from two NOR blocks in much the same manner as the present Cypak magnetic Memory is constructed from two blocks.

Even though it first appears that a greater number of NOR elements are required to accomplish a specific function than are English logic elements, this is not necessarily the case. Simplification in the logic procedure can be made but it involves a reorientation of thinking toward NOR logic. Functions can be constructed from NOR equivalents of English logic and then simplified according to rules which allow elimination of redundant blocks. Familiarity with the use of the NOR block will allow a skilled logic designer to think in terms of the NOR as a logic element, rather than convert English logic to NOR hardware. The advantage of using only one universal logic block must be weighed against the disadvantage of having to use an unfamiliar logic block, and one for which the Boolean algebra is somewhat less straightforward.

Many logic blocks need not be restricted to only two inputs. The NOR is one such block in that it can have many input wires; from it there is an output only if all of the inputs are zero. Resistors are connected in series with the input terminals to isolate each input from the others. The collector supply potential and its series resistor is normally common to all the NOR blocks in one arrangement, and a bias voltage with a series resistor is usually added to minimize the effect of increased leakage at elevated operating temperatures. A description of the transistor circuit design and the choice of circuit parameters is given in "Transistor Nor Circuit Design," an AIEE

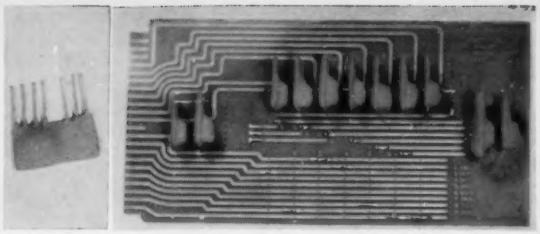


Fig. 5. Experimental transistorized NOR package and board

Paper which was presented at the Winter General Meeting in January, 1957. One adaptation of a transistor NOR unit experimental package is seen in fig. 5. The transistor is mounted on a steatite board with resistors and circuits printed directly on it, and the entire subassembly is dipped in a resin protective coating.

The board illustrated contains provision for 14 NORs and the associated interconnections. In addition to the direct wiring associated with the NOR logic this particular board has a selection matrix which enables the designer to select a predetermined output code by drilling and inserting pins to connect from the top printed circuit to the bottom one. The dimensions of the board are 4 in. by 8 in.; and spacing of about one inch is needed between boards so that the volume per NOR for these 14 NORs and the selection matrix amount to a little over two cubic inches per NOR. Other specialized circuit boards would have considerably less volume per NOR.

Environmental tests have provided very encouraging results. After an initial aging cycle, 163 units selected at random were operated for 7,200 hours at ambient temperatures between 15C and 35C, giving a total life of 1,180,000 transistor hours without any failures. END

Feedback control principles — cont.

sooner because of this field forcing. It is evident that some means is required to catch the generator voltage before it becomes too high; this is the purpose of the differential field across the generator terminals, which opposes the main field as generator voltage increases. The result is a rise of field current intermediate to the two curves, but with a distinct improvement in response time, as shown in fig. 8. The anti-hunt in this case is a direct feedback opposing the main actuating signal, rather than a rate feedback. The fundamental effect is similar, however, in that the anti-hunt signal acts to prevent dangerous or undesirable conditions from arising.

In discussing control principles underlying operation of the largest to the smallest regulated drives, emphasis has been placed on basic similarities. The form, size and shape, as well as the quantity to be regulated, may be drastically different from one system to the next. No attempt has been made to describe all the different types of regulators in common use, such as voltage, current, speed, tension, position, or power regulators, to mention a few. In analyzing each of these systems, however, it is interesting to note that each system can be reduced to a block diagram, which represents components of the overall system.

Various combinations of positive and negative feedback, including special phase-shifting elements, all help the designer modify component time delays to get good, stabilized operation. However, his problem is further complicated by the fact that component gain and time delay values can change with operating conditions. For example, a d-c generator operating on the lower portion of its saturation curve has higher gain and higher time delay than when operating in the saturated region. The same is true for a d-c motor, with the added complication that the mechanical time delay also changes non-linearly. Consequently, a system must be designed to give satisfactory performance under the worst possible condition of operation. END

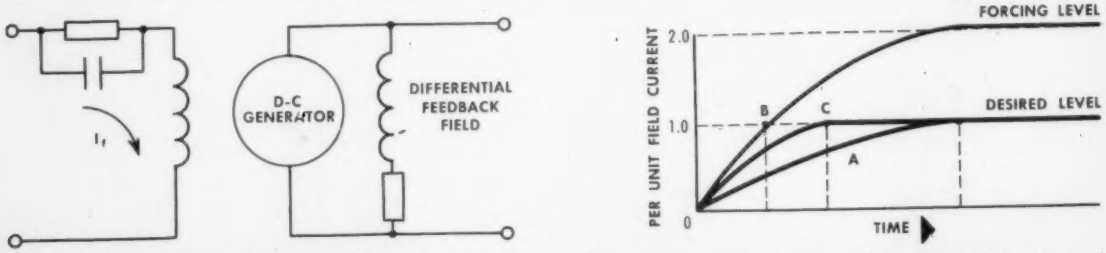


Fig. 8. Field forcing minimizes the effect of time delay of a dc generator. Effect of the differential field in opposing main field is illustrated by curve C, a response intermediate to A with no field forcing, and curve B at field-forcing level

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Spotlight is on Canadian designed transmitter

One of the exhibits that attracted a lot of attention at the National Association of Radio and Television Broadcaster's Convention in Chicago was the new Canadian General Electric 50 kilowatt am transmitter. One comment was that it was about "the biggest advance in transmitter design in years."

Harold E. Fellows, president of the NARTB inspects the Adler television translator transmitter at the Chicago convention. Translator picks up station signal and directs it to the shadow area

The new transmitter shows a considerable reduction in size, weight and tube complement compared with more conventional units. It uses germanium rectifiers for high-voltage supply and new design of the power amplifier tubes eliminates much of the heavy cooling apparatus normally used.

The RCA Company had one of the largest displays, feature of which was two closed circuit TV systems. The same subject was viewed simultaneously by a monochrome and color cameras, producing pictures which could be viewed side by side.

For fringe areas

One of the more interesting pieces of equipment was the translator-transmitter of Alder Electronics, Inc. These small, self-contained stations receive a vhf signal from a distant station, translate it to uhf and rebroadcast it to "fringe" or "shadowed" areas.

This method of televising should prove a boon to small communities which cannot afford a vhf operation and want TV reception. The Adler equipment may be remotely controlled and has an antenna which can be adjusted for either directional or omnidirectional operation.

Automatic broadcasting

A great amount of discussion centred around the topic of "automation for broadcasting." In line with this the Gates Radio Company came up with an assembly of equipment called the "auto-station." In this system of practically automatic broadcasting the production unit uitilizes a binaural magnetic transport.

One half of the tape carries the sound portion of the recorded programs; the other half has applied to it various inaudible tones which trigger the automatic operation of the playback units. The automatic playback unit, using the tape from the production unit, takes care of the actual broadcast, timing announcements, starting disc records, and in general scheduling the program material for hours at a time.

Single-sideband will solve AM problems

Among the many engineering papers given at the NARTB was an outline of a system of single side band am broadcasting. According to Leonard R. Kahn of Kahn Research Laboratories, this system if adopted in North America would allow an increase in the number of am broadcast channels, reduce present interference, reduce fading and distortion of signal, and give an increased signal to noise ratio.

Color tape recording

Howard A. Chinn of CBS Television Engineering gave a paper on five months experience with the Ampex videotape. While there were still difficulties the tape has proved itself under rigorous operational conditions and is fast replacing kinescope recording in delaying network programs for different time zones.

In the main the videotape has lived up to its vast promise and in the near future will be extensively utilized by individual stations as well as networks.

Special reports on the NARTB Convention were written by Gerald W. Lee, P.Eng., Consulting Engineer, Toronto.

Channel switch for stations?

Rumors that the FCC were going to rule that all stations presently occupying vhf channels be moved to uhf, and that the vhf part of the spectrum be relinquished kept cropping up during the NARTB convention.

Reasons for the possible shift appear to be the shortage of vhf channels and the fact that defense communications might require them.

NEW DESIGNS FOR PRINTED CIRCUITS AT BRITISH SHOW

Nearly 24,000 people, including representatives from 28 countries abroad, visited the British Radio and Electronic Component Show in London.

The U. S. A., Britain's best customer for high-fidelity equipment, sent 26 buyers to the Exhibition, more than ever before and some paying their first visit.

Australia, biggest buyer of small components, sent five buyers. France led with 86 representatives and there were 45 from Holland, 32 from Belgium, 13 from Canada and 11 from Russia.

Printed circuits

The exhibits of 160 firms and two government departments showed two main trends—greater reliability of the conventional component and new designs for sub-miniature work and printed circuitry.

For printed circuitry much attention has been concentrated on suitable mountings and "clip-in" or "snap-in" arrangements for the heavier components such as electrolytic capacitors and output transformers.

The influence of automation was also seen in components for computers such as miniature germanium junction photocells, only 0.08 in. in diameter, for scanning punched card and perforated tape and high permeability metallic alloy strip only .0002 in. thick for computor cores.

Production soars

In the ten years, 1946-56, Britain's production of radio and electronic components has increased six times to a total last year of 1,500 million (valued at $212 million, and compared with a volume of 1,400 million valued at $192 million in 1955). Exports in the same period increased over seven times in volume.

IDEAS, TOO,

FROM SEA TO SEA

No other nation in history has depended for its very existence on strong lines of communications as has Canada. No nation has been better served by them.

Two railways, an air line, a pipe line, a highway, two telegraph systems and a waterway reaching from the Lakehead to the sea knit Canada together as a single unit. Communications are the basis on which Canadians have built their great commercial and industrial development.

But the communication of ideas is as vital to national growth as is the movement of goods and provision of services. That is the job being done by Canadian magazines and business papers. They serve all groups and areas in the country. The Massey Commission called them "our closest approximation to a national literature." In a young and widespread country like Canada you could not develop commerce or culture without national periodicals. They, too, are essential threads in the fabric of our national life.

As publisher of three magazines, four business newspapers and 31 other business publications, Maclean-Hunter Publishing Company is a part of this important group.

Through their news columns, Maclean-Hunter editors give national significance to many events that would otherwise receive only regional attention. They put national events in perspective that gives them new meaning to people of all regions. They comment vigorously on national issues, from a Canadian point of view.

All Maclean-Hunter editors are dedicated to the principles of accuracy, honesty and fairness. Together they provide unbiased news and sound opinion to more than 3,000,000 readers. We're glad that you are one of them.

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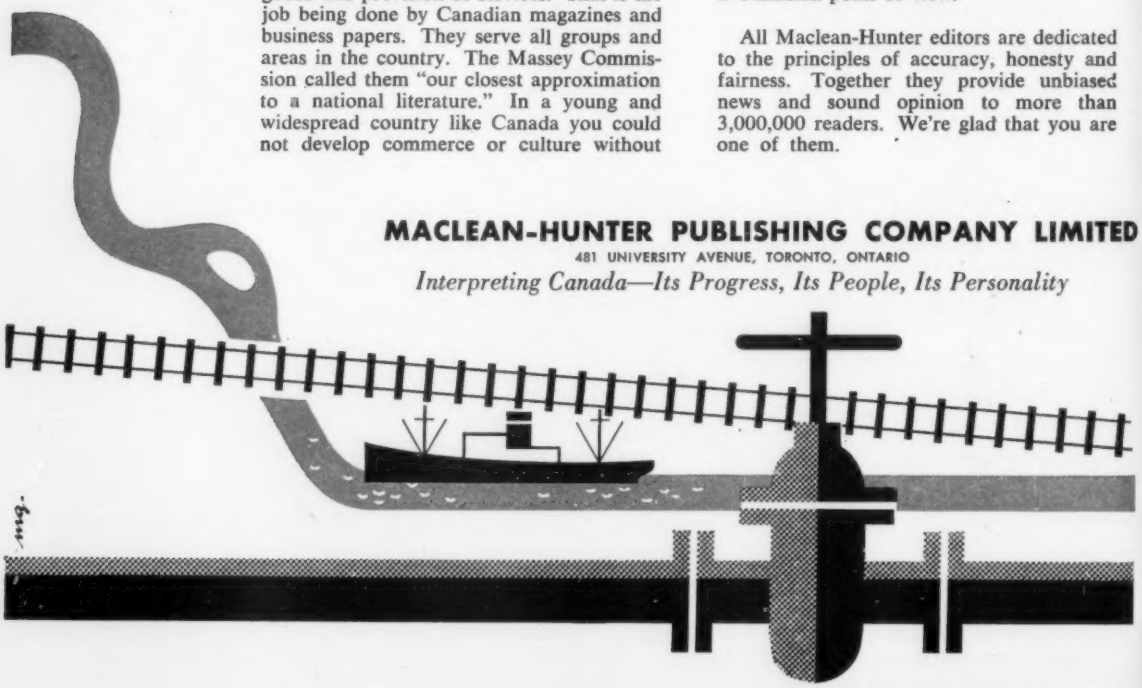


Canada needs many more student engineers

Still room for initiative
Atom power costs sag
Get the best from planning
Exchange of engineers
A new yardstick

Wilcox

The shortage of engineers has now reached a point where an industrial manager hardly dares send them out to recruit other engineers. One company in the U. S. recently sent seven engineers to a technical convention to see if they could recruit from among those in attendance — and five of the seven just never came back. They had been recruited by other company scouts at the same convention.

In Canada, the engineer shortage is beginning to have serious effects in many areas. In our own field the pressure seemingly is not quite so great as it was, but the shortage still exists. The enrolment of young people in engineering schools is increasing, but not as fast, by any means, as the estimated demand.

There is certainly good evidence that the engineer shortage will be with us for a good while to come. In fact, it may be that there never again will be a surplus of engineers in this country.

G. L. WILCOX
President,
Canadian Westinghouse Co. Ltd.

Creative Outlook Still Needed

Strange as it seems, if Thomas A. Edison and the Wright brothers were 20 years old today, they would have great difficulty in finding technical positions worthy of their talents in American industry.

Most companies largely ignore the creative mentality in selecting young engineers, and if a young engineer is creative, his initiative and inventiveness may be stifled rapidly in the organization of the average industrial corporation. Moreover, a college engineering degree in itself is no passport to success in advanced electronic research and development.

We seem to have forgotten that many of the basic technical inventions —the electric light, the phonograph, and the airplane—to name but a few, were made by men without an engineering degree. There are now many research problems which can be solved only by teams of men with formal scientific training, but the day of the 'attic inventor' is not past in electronic development.

CARL G. SONTHEIMER
CGS Laboratories Inc.

Nuclear power costs will come down

Recent studies of designs for large atomic power stations suggest the possibility that the heavy water moderated reactor might within ten years show a cost advantage over the gas-cooled, graphite moderated reactor and maintain this lead for many years.

In Canada, where relatively large amounts of inexpensive hydro-electric power are available, nuclear power stations will provide for a large fraction of the rapidly growing demand for electrical power only if the cost of nuclear power can be brought to less than six mills per kilowatt hour. Whereas Chalk River scientists and engineers were not able to see six years ago how this cost target could be met, it now seems just possible.

DR. W. B. LEWIS
Atomic Energy of Canada Ltd.

Planning means sitting— and thinking

Planning projects started with civilized man. There are many early examples. One I like to think of is the project Noah was faced with in building the ark. He had real problems of scheduling, designing and estimating. Planning is an old subject. Everyone of us knows all about planning, but look at the examples of bad planning all around us. Town planning is hopelessly bad. We are sure of this every time we try to find a place to park.

We all know that really worthwhile thinking comes best from applying pants to chair and pencil to paper— this is surely our experience in studying for examinations and is true of the great technical leaders like Da Vinci, Newton, Maxwell and Einstein.

J. M. TOYE
Canadian General Electric Co. Ltd.

Engineers come and go in Canada

One third to one half of Canada's engineers go to the United States to work. The migration is not a total loss to Canada because we get much goodwill in return. Canada also gets engineers from Europe and Great Britain.

Salary differences between the U. S. and Canada are not too marked but there are fewer openings for engineers in Canada.

Small commercial research laboratories are just starting to grow in Canada. It may be 10 or 20 years before they play a major role in Canadian electronics. The government is now the leader in the field.

JOHN T. HENDERSON, IRE PRESIDENT

Putting a country in its place

In the past yardsticks which were frequently used to measure the relative industrial status of a country were its iron and steel output, its output of heavy chemicals and so on. It may well be that in future the number of television sets used will furnish a measurement of the standard of living in a country; the quality of the television programs will provide an index of its general cultural level; and the proportion of electronically controlled or automated machinery will supply an accurate barometer of the efficiency of its industry.

THE ELECTRONICS INDUSTRY IN CANADA

Both manager and scientist

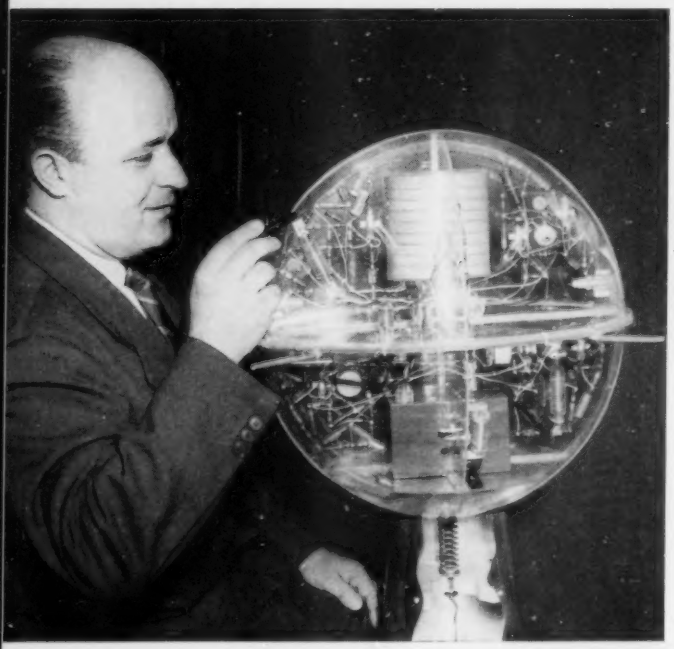
The engineer often becomes a manager but he should always remain a scientist. As a manager he will have little time to wonder; but as a scientist he has a duty to wonder. And if he finds a few moments to wonder now and then, he will be a better manager of men.

SIR GEOFFREY VICKERS, V.C.

Micro pictures that tell the inside story

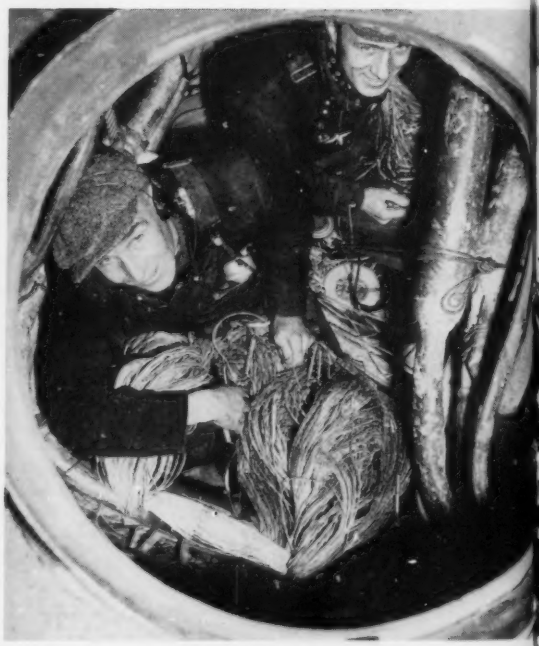
JUST THE HEAD OF A FLEA

Microradiograph picture of a flea of a cat (Ctenocephalus Felis) by Philips shows clearly the internal structure of the head and part of the body. Magnification, made optically by a light-microscope, is 125 diameters



GOING UP!

During the International Geophysical Year which opens on July 1 man-made satellites will be launched to orbits of 200 to 300 miles in space. This model weighs 25 pounds, is 18 inches in diameter and shows instruments inside

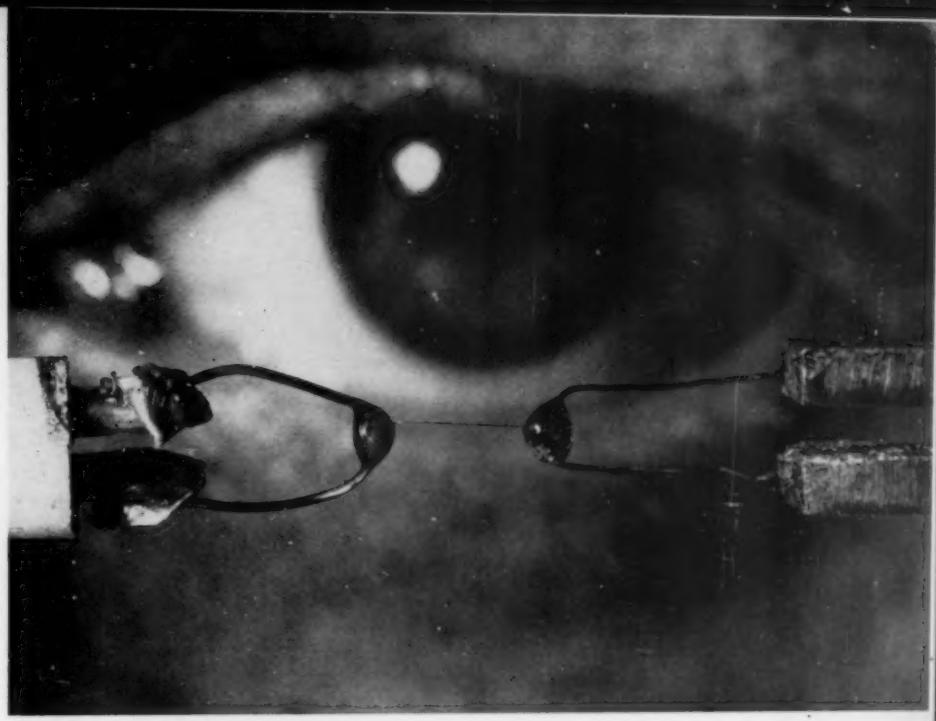


TAKE A LOOK AROUND

Just turn the page around and watch how those men in the manhole keep looking the right way. Picture was taken as some work on splicing telephone cables at a busy junction was being done

PICTURE OF THE MONTH

Tiny iron whiskers, such as this one, are being studied by Westinghouse scientists who stretch the whiskers in experiments on research into the atom. Loops of wire to which the whisker is attached are only a few thousandths of an inch in diameter.



AN EYEFUL OF IRON WHISKER

CIENTIST MAKES MOVIES

r. George P. Fulton of Boston niversity adjusts camera for taking icroscope movies of blood flowing rough arteries and veins of a hamster. ovies were for Bell System production, emo the magnificent.

NOW IT'S A MUSEUM PIECE

Dr. James Hillier (right) looks at the first electron microscope he designed at the University of Toronto 17 years ago. Dr. Hillier, born in Brantford, Ontario, now heads RCA Laboratories. With him is Dr. G. D. Scott

THE TALKING TOWER

Part of the Trans-Canada telephone system microwave network, this tower at Red Rock, near Nipigon, Ontario was erected by the Bell Telephone Company. To get to the site engineers had to blast a road through 225 feet of rock

Color television experts have all the answers

Hazeltine engineers write
New electronics textbook
Transistors listed
Up-to-date on semiconductors
Product catalogues

Principles of Color Television

Hazeltine Laboratories staff, edited by Knox McIlwain and Charles E. Dean. 595 pp. John Wiley & Sons Inc., New York, $13.

Color television progress over the past few years has been remarkably rapid. Innumerable papers on various developments have been published; now comes a welcome book which presents the design of color television equipment and its underlying theory.

The book is based on the experience of the Hazeltine engineers, a group which includes many distinguished men who between them have contributed much to the literature of color television and have given over one hundred talks on the subject to professional groups in the United States and Europe. They also had a big hand in the formulation of the operating standards for color TV by the National Television System Committee.

Treatment of the subject in the book itself assumes a familiarity with the engineering theory and techniques of monochrome television, including a fair mathematical background. It is written to help the many practicing engineers who want to move into the color field. It should also be a great help to the graduate engineer who wants to work in the color television development field.

The book starts with a number of sections on basic principles, including a very good discussion of the quantitative handling of color. It then deals in commendable detail with the features of transmitting, receiving and measuring equipment. Chapters on the design of receivers includes questions of synchronization, r-f, i-f and video amplifiers and decoders.

There is also a study of FCC transmission standards, a glossary of color TV terms and several appendices. (530)

Electric circuits and machines

B. L. Robertson & L. J. Black; D. Van Nostrand (Canada) Ltd., Toronto; 434 pp.; $7.25.

This book, written by two professors for use as a text, is a logical presentation of the basic elements in electricity and electronics. As a text book, it should meet its obligations well with its organized approach through basic principles to electric and electronic circuits.

The numerous problems taken from actual practice will help the student consolidate his knowledge. The graduate electrical engineer will find the book to be a valuable reference on the subject of electronics; the electronic engineer will find similar help with motors, generators and electric circuits.

A useful service is rendered in Appendix II with the discussion on "Operator j" and how to apply it in electrical calculations. This should clear away the fear many students hold for the basic mathematical concept.

If the publisher plans a revision, the electronics portion of the book could be strengthened by inclusion of recent trends in such areas as klystrons, magnetrons, waveguides and semiconductors. (531)

Transistor Engineering Reference Handbook

John F. Rider, Publisher Inc., V. W. Pointon Ltd., Toronto.

This book is designed to be used as a source reference for technical information on transistors and components designed for use with transistors. Operating capabilities, performance characteristics, and sources of supply are discussed. The development engineer will be assisted by the technical information on some 200 types of transistors along with the associated components (capacitors, cells, batteries, thermistors) for transistorized equipment. (532)

Handbook of Semiconductor Electronics

Edited by L. P. Hunter. 586 pp. McGraw-Hill Co. of Canada Ltd. $14.40.

Since the invention of the transistor in 1948 a wealth of information has been published in journals and books on various aspects such as theory, production and applications. This book, however, is the first successful attempt to present a concise, over-all picture of the subject as it exists today. Thirteen qualified authors have pooled their technical knowledge, each contributing in the area of his particular experience.

Part 1. "Physics of Transistors, Diodes and Photocells," is a description of transistor action and the basic physics of electrical conduction in solids.

Part 2. "Technology of Transistors, Diodes and Photocells," describes the basic production processes and techniques. This will be of particular value to the design engineer in making him aware of the limitations as well as potentialities of the various transistors.

Part 3. "Circuit Design and Application," is an excellent presentation of the information the circuit designer requires. Examples, equivalent circuits and mathematical analyses are given for most of the presently known circuits, including amplifiers, oscillators and switching circuits.

Part 4. "Reference Material," provides the reader with auxiliary information to help him understand the text and utilize his new knowledge. A further useful service is rendered by the 68-page Bibliography of major papers and books on semiconductors, transistors, rectifiers and related material.

This handbook will be a valuable addition to the electronic engineer's library. (533)

Counters and timers

Computers - Measurements Corporation, Electromechanical Products, Agincourt, Ontario.

For convenient reference on their electronic counting, timing and controlling instruments, Computer-Measurements Corporation have recently issued their new Short Form Catalogue.

Among the many instruments shown are universal counter-timers, frequency and period counters, time-function translators, preset controllers, totalizing counters, time interval meters, decade and preset decade counting units. (534)

New Catalogue

J. W. Ellis Industries, Toronto

For many years past the Sodeco technical literature has dealt exclusively with the small panel mounting electric impulse counters of the TCe series. Their new folder is the first complete catalogue ever published dealing with the standard size impulse counters of Sodeco Ti series (535)

Vital job for Radio Amateurs

In event of an emergency ham radio operators would play a big part in Canada's civil defense. Discussing this, and other problems, are Major General Worthington of Ottawa, Federal Civil Defense Co-ordinator, R. C. Poulter, P.Eng., Radio College of Canada, W. F. Choat, chairman of Amateur Radio Emergency Corps and M. I. Coombes, communications officer for Civil Defense, Ontario

Hopkins, Canadair chairman, dies

John Jay Hopkins, 63, builder of the first atomic submarines, died recently in Washington, D.C. He was suffering from cancer.

Mr. Hopkins, founder and chairman of the board of General Dynamics Corporation, with headquarters in New York, and chairman and managing director of Canadair Limited, Montreal, gained a unique place in world industry.

During his 20 years association with the organization, which until 1952 was known as the Electric Boat Company, and after that as General Dynamics Corporation, Mr. Hopkins developed the corporation from a small submarine shipyard to one of the world's great industrial enterprises.

Mr. Hopkins joined Electric Boat as a director in 1937. In 1942 he became vice prseident in charge of financial and contractual matters, and in 1946 initiated Electric Boat's acquisition of Canadair, the great Canadian aircraft company. He became president of Electric Boat in 1947.

Executive training by new "game"

Eric W. Leaver, president of Electronic Associates Ltd., of Willowdale, Ontario, was among 20 company presidents who took part in the first "business war game" in New York. This is a new executive training device developed by the American Management Association.

Chief purpose of the game is to give presidents and would-be presidents intensive practice in the analytical techniques of decision making.

DRTE chief receives Fellow award

J. C. W. Scott, chief superintendent of the Defence Research Telecommunications Establishment of DRB, Ottawa, is the third Canadian to receive the Institute of Radio Engineers Fellow Award this year. The award was for "contributions in the field of ionospheric propagation."

Mr. Scott attended the University of British Columbia then later obtained a B.Sc. from the University of Washington in Seattle. Before the war he was a physicist with the Bell Telephone Laboratories in New York.

He served overseas as a radar officer with the RCAF and in 1944 became RCAF Scientific Member on the newly formed Canadian Wave Propagation Committee. On the organization of the DRB in 1947 Mr. Scott was one of the three scientists who formed the nucleus of today's Radio Physics Laboratory.

Carl A. Pollock, president, speaking at opening of Electrohome's new Kitchener plant (see story on page 9)

Reports from industry

General Dynamics double earnings

Increase of 93% in net sales and 103% in net earnings for the first quarter of 1957 over the same period of 1956 is the record of General Dynamics Corporation. One of the Corporation's divisions is Stromberg-Carlson.

First quarter sales for 1957 totaled $334,607,000, compared with $173,473,000 for the same period last year and that net earnings went from $4,322,699 in the first quarter of 1956 to $8,793,767 during the first quarter of this year.

Reports from here and there

Hoffman Radio Division of California have added hi-fi components to its consumer products line. These include an amplifier, record changer, am/fm tuner and sound chamber.

Canadian Electrical Supply Co. Ltd. have opened a new branch at 110 Ouest Rue St. Vallier, Quebec. Their head office is in Montreal.

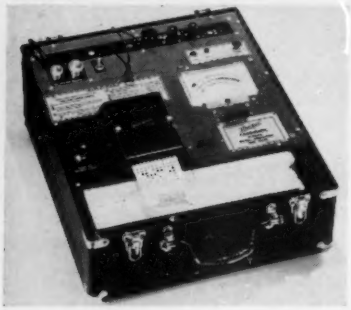
Electrodesign of 736 Notre Dame St. W., Montreal, and 109 Eglinton Ave. E., Toronto, have been appointed exclusive Canadian agents for Siemens flat and block selenium rectifiers.

Allied Electronics Ltd. has established a plant in the Chinook Air Services building at the McCall airfield in Calgary. A total of 93 aircraft operate from the airfield. AEL is a wholly owned subsidiary of Technical Enterprises Ltd. of Malton, Ontario.

Punched cards guide tube tester

D-C microvoltmeter
Automatic programmer
2-12 mc aircraft radio
Missile data recorder
Servo analyzer

The Hickok Company have utilized a punched card system in their new sensitive tube tester Model 123. The vinyl-type cards of the Cardamatic



Tube Tester are inserted into the automation mechanism to set up the electrical connections required for the particular type of tube under test. This reduces testing time by eliminating the customary procedure of manually setting the appropriate switches.

To test the newer more sensitive type tubes while avoiding test distortion, the Model 123 uses a grid signal of only 0.22 volts rms. In addition, tubes can be tested on the "knee" of their curve—a test which is necessary in evaluating the ability of a tube to work in a TV sweep output circuit.

Stark Electronic Instruments Ltd., Ajax, Ont. (536)

A recording microvoltmeter

Newly introduced to Canada is the Kipp Micrograph, a quick-acting d-c recording microvolt meter having a sensitivity of 50 microvolts for full-scale deflection, one second speed of indication and accuracy within 1%.

The voltage to be measured is detected by a mirror galvanometer which forms part of a d-c to a-c photoelectric amplifier. The light reflected by the galvanometer mirror falls on a combination of photo cells and the displacement of the light spot results in an a-c signal. This signal is amplified and used to operate a servo motor driving a potentiometer. As a result, the galvanometer receives a compensating voltage causing it to return to zero. In this way, the potentiometer which is connected to the pen arm is a linear function of the input voltage and is independent of the linearity of the amplifier.

A safety relay protects the movement from overload. Charts are 52 ft long with rectangular co-ordinates and can be driven at speeds of 120, 450 or 1,800 mm/hr.

R. H. Nichols Ltd., Toronto. (537)

Automatic broadcast programmer

Automatic unattended operation of programming systems for radio broadcasting stations is now possible with the Gates M5429 Autostation.

This is a completely automatic programming system for radio broadcasting stations, incorporating facilities for both tape and 45 RPM discs. It is

composed of two basic pieces of equipment — the production unit and the playback unit. The production unit is not used for actual broadcasting, but for program make-up including control tones for automatic operation of a record changer, and two tape playback units.

When made up in sequence, the production tape is placed on the playback unit, which is used for actual broadcasting. The announcements on the tape trigger the 100 disc record player or optional tape playback units which operate unattended, providing up to 14 hours of automatic programming. Illustrated is the automatic playback unit.

Canadian Marconi Company. (538)

Flexible epoxy

Hysol 6900 series represents a new, economical, flexible epoxy potting and casting system. Moderate cure at 75°C permits encapsulation of delicate, temperature-sensitive electronic components. Other applications include the potting of coils, amplifiers, connector plugs, transformers and submersible assemblies.

Sold in two-component units in three sizes, the 6900 series currently includes both filled and unfilled versions with two degrees of flexibility for each type.

Hysol (Canada) Ltd., Toronto. (539)

Ten channel hf radio

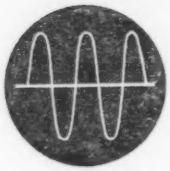
Aviation Electric Ltd. has announced a new Hamlyn HF Radio unit. This new HTR-10 model is the same size, weight and style as the HTR-5, but provides 10 preset channels with a 10 position frequency switch. The HTR-5 model can be converted into an HTR-10 model by means of a low-cost conversion kit.

Specifications: Frequency Range: 5 or 10 preset channels between 2 and 12 mc; Power Output: 30 to 50 watts . . . ensuring maximum range; Weight: Only 34 lb. complete, including remote control and self-contained power supply; Modulation: 100% with speech clipping; Receiving Sensitivity: Better than 3 microvolts for 100 milliwatts

output; Power Requirements: At 27.5V d-c input, only 2.8A for receiving and 9.8A for transmitting.

Aviation Electric Ltd., Montreal. (540)

(Continued on page 53)



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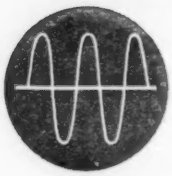

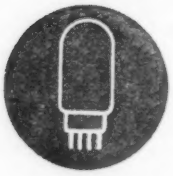

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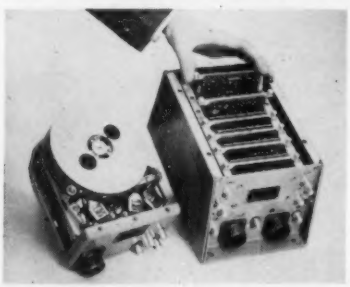
Miniature recorder check on missiles

A completely automatic miniature record-playback system for data acquisition during missile flight has been introduced by Minneapolis-Honeywell Regulator Co., Davies Laboratories Div. With the application of a 28VDC signal, the Model 600 automatically records two tracks of IRIG FM/FM subcarrier signals from 200 to 100,000 cps for a preset period ranging up to 250 seconds. The application of a second signal causes the Model 600 to play back all recorded data backwards and then stop. Successive signals repeat the cycle, erasing all previous data before recording new information.

The entire system weighs approximately 21½ pounds, and is small enough for mounting directly in the missile. The transport itself weighs just 9 pounds. Coaxially mounted reels carry 1,200 feet of ¼-in. mylar instrumentation tape. Standard tape speed is 60 ips.

The Model 600 Electronic Housing accepts two recording and two playback amplifiers, a bias oscillator for erasing, a reference generator for flutter-and-wow compensation, and a 400-cycle inverter. Electronic compensation holds flutter-and-wow content below 1% peak-to-peak for a signal-to-noise ratio of 30db with 2% maximum harmonic distortion. All recording and playback electronics are on plug-in printed cards for maximum system flexibility and reliability.



Honeywell Regulator Co., Toronto. (541)

Precision gear cluster hub

A complete stock line of type "BH" precision gear cluster hubs has been announced by PIC Design Corporation. These units are used as adapters for their "J"-type gears, offering a large selection of combinations in pitch, such as 48, 64, 72, 96, and 120. Materials are stainless, aluminum phenolic and nylon. These hubs are made of No. 303 stainless steel and are clear passivated.

PIC Design Corporation, East Rockaway, New York. (542)

Heavy Teflon tapes

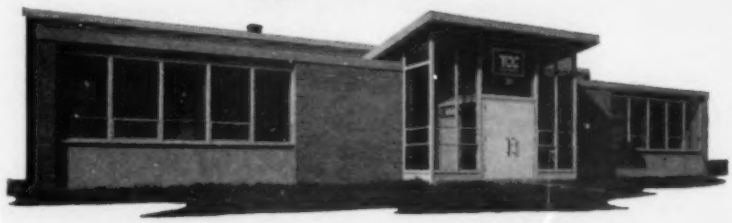
Teflon continuous-roll tapes are now available in thicknesses to 3/16 inch. Length from 40 feet to several hundred feet are available in thicknesses of 3/32 in., ⅛ in., 5/32 in., and 3/16 in. Maximum width varies from 6 inches to 12 inches depending on thickness.

These new heavy Teflon tapes are available in virgin Teflon, TFMC (Mechanical-Chemical) and Enflon (filled Teflon) and also in cementable or pressure-sensitive types.

Enflo Corporation, Pennsauken, N.J. (543)

(Continued on page 54)

Now!



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SALES OFFICE: 44 Wellington St. E., Toronto EM. 6-5673
FACTORY: 50 Bertal Rd., Toronto 15, Ont. RO. 6-6123

Transistors used in two instrument circuits

Transistors have been used in two new self-powered instruments. These are the square wave generator and the a-c decade amplifier introduced by Burr-Brown Research Corp.

The model 100 a-c decade amplifier is basically a two-stage feedback am-

plifier with most of the internal circuitry direct coupled by temperature stability and minimum low frequency phase shift. Approximately 35 db of feedback is employed for gain stability and frequency response and the gain selection of either X10 or X100 is made by altering the feedback factor. Specifications are:

Gain, X10 and X100 (open-circuit voltage) Non-inverting; Accuracy, 2% at 1,000 cps; Frequency Response, +0.5 db, —0.5 db, at 5,500,000 cps and ± 0.5 db, —3.0 db, at 1-800,000 cps; noise figure, approximately 6 db.

The model 200 square wave generator employs two transistors in a multivibrator circuit, and two more transistors as current regulators to ensure flat wave forms. The frequency of the output is controlled by a single capacitor which may be selected internally or externally. Output signal level control is provided by a simple voltage attenuator in the output circuit. Specifications: frequency range, 5,30,000 cps; rise time, 0.25 microseconds; internal frequencies, 60,600 and 6,000 cps; other frequencies, connect to an external capacitor.

Both instruments weigh three lb. and are 7½ in. by 3¾ in. by 3½ in.

Burr Brown Research Corp., Tucson, Arizona. (544)

High frequency transistors

The Canadian General Electric Co. Ltd. has announced three new high-frequency germanium tetrode transistors that are expected to extend the application for transistors into equipment now limited to vacuum tubes.

The three new transistors have been designated 3N29, 3N30 and 3N31. With a common base connection and a bandwidth of 2 mc, they are rated for a minimum of 10 db gain respectively at 30 mc, 120 mc and 15 mc.

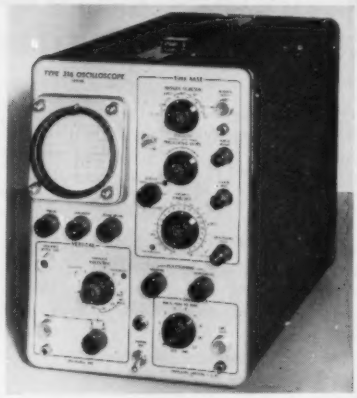
Maximum collector dissipation for all three units is 50 milliwatts at 25°C. They are rated for operation at a maximum junction temperature of 85°C and the allowable collector voltage is 7 volts.

For receiver local oscillator use, the 3N29 has an oscillating frequency of 50-60 mc; the 3N30 will oscillate at over 200 mc and the 3N31 at 30 to 40 mc.

Canadian General Electric Co. Ltd., Tube Marketing, Toronto. (545)

Wide pass-band oscilloscope

The Tektronix Type 316 Oscilloscope combines a dc-to-10 mc pass-band, high sensitivity, and wide sweep range in a compact instrument that weighs only 35 pounds and measures only 8½ in. wide, 12 in. high, and 19½ in. deep. Vertical-amplifier specifications include 12 calibrated deflection steps from 0.01 v/div to 50 v/div with ac-coupled steps from 0.01 v/div to 0.05 v/div; 0.035-μsec rise-time from 0.1 to 125 v/div, 0.04-μsec risetime from 0.01 v/div to 0.1 v/div; balanced 0.25-μsec delay network.

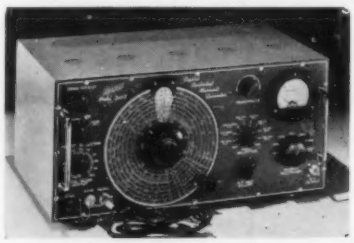


Time base specifications include 22 calibrated steps from 0.2 μsec/div to 2 sec/div, accurate 5x magnifier, cersatile triggering circuitry with preset stability for all triggering modes. Other features are 1.85-kv accelerating potential on a new Tektronix precision 3-in. cathode-ray tube with 8-div by 10-div linear viewing area, electronically regulated power supplies, and square-wave voltage calibrator.

Tektronix, Inc., Portland, Oregon. (546)

Microvolt signal generator

The Hickok Model 295X is a Microvolt Signal Generator, primarily intended for the servicing of modern receivers used by aircraft, railroads, police, taxi cabs, utilities and industries. The sensitivity of the receiver



can be determined without use of correction factors or reference tables. This unit features a wide range of frequencies both variable and crystal controlled, wide range of metered output voltage, stable frequency and calibrated RF output level as low as 0.1 microvolts.

The frequency coverage on the Model 295X is available on fundamentals from 125 kc to 175 mc.

Stark Electronic Instruments Ltd., Ajax, Ont. (547)

(Continued on page 55)

Semiconductor Scientist

Semiconductors, Ltd., organized by Plessey Ltd. and Philco Corporation, is seeking a top grade professional scientist to organize and guide the manufacturing, design and research of existing and new transistors. American type facilities will be established near London for this assignment. The applicant should have an educational background in Physics, Chemistry, Electronics, or other suitable fields of science, with some professional managing experience.

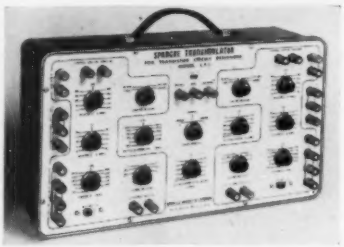
It is an excellent opportunity for a British subject, who is aggressive technically, and has the ability to organize both professional and semi-skilled personnel. Salary commensurate with responsibility, and fringe benefits typical of a large company are available.

Send resume to
Mr. Charles Lupton,
Lansdale Tube Co.,
Church Road, Lansdale,
Pennsylvania.

Simulator helps to spread design work

A new instrument that eliminates breadboard layout by simulating complete transistorized amplifier stages has been introduced by the Sprague Products Company.

Any a-c or direct-coupled amplifier stage short of high power audio output can be simulated with the unit, as can multivibrator, switching, phasing, push-pull, Class A and B circuits, and others by using cross-coupled Transimulators. Common or grounded emitter, base, or collector circuits may be simulated using PNP, NPN, or Surface Barrier Transistors. A separate Transimulator can be used for each stage to permit simultaneous multistage operation, or circuits can be simulated stage-by-stage for cascade operation.



Everything required for r-c amplifier circuits is built right into the instrument, including 2 uf and 20 uf direct coupling capacitors and posts for external coupling on both Input and Output.

Built-in battery voltage supply for separate bias and load provides 1.5, 3, 4.5, and 6 volts d-c. Switch reverses polarity. Almost any external connection desired, including meters, transformer coupling, external supply voltage, degeneration, bypass, coupling, signal input and output, can be made at the 5-way binding posts provided on the face of the Transimulator.

Sprague Electric International Ltd. (549)

N-P-N junction transistors

The General Electric Co. has made improvements in their line of n-p-n if transistors to provide increased power gain and greater uniformity. The new line of transistors have been designated to 2N293, 2N168A, 2N169/2N292 and 2N169A.

Full information is available from your nearest Canadian General Electric Co. Ltd. office. (550)

Miniature instruments

Taut suspension—without pivots or bearings—permits the production of moving coil instruments that are light weight, compact and virtually shockproof according to the manufacturer. Weighing only 3.53 oz. the new H & B Elima model K15DC microammeters and millivoltmeters are easy to read because of their long scales (2.76 in.).

The standard ranges of d-c microammeters run from 25 microamps (6,000 ohms) to 25 milliamps (2.4 ohms) with higher ranges by means of separate 60 mv shunts. The standard ranges of the d-c millivolt and d-c voltmeters go from 100 mv to 600 mv (200 ohms per volt) and from 1 volt to 250 volt (1,000 ohms per volt—above 1 volt through external series resistors). The standard accuracy is ± 1.5% but higher accuracy, calibration with separation rectifiers or thermocouples, etc., are also available.

The J. W. Ellis Industries. (551)

(Continued on page 56)

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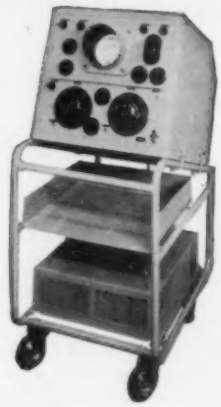

The Marconi HF Spectrum Analyser provides an instant, panoramic visual presentation of the frequency spectra of signals in the 3 to 30 Mc/s band. It is perfectly suited to measuring single-sideband transmitter and drive-unit characteristics.

In addition, intermodulation distortion, noise level, carrier compression, crosstalk, etc., can be quickly and easily seen and evaluated against the c.r.t. graticule.

A continuously variable sweep width allows observation of a whole broadcasting transmission bandwidth, or of only a few cycles for accurate separation of closely-spaced components. A high order of selectivity assures discrimination between signals of widely differing amplitudes but as little as 50 c/s apart.

Input Frequency Range:	3 to 30 Mc/s in 9 bands with separate fixed frequency input of 3.1 Mc/s
Spectrum Width:	0 to 30 kc/s
Sweep duration:	0.1, 0.3, 1, 3, 10, and 30 sec.
Amplitude Measurement Ranges:	0 to—30 db, and—30 to—60 db, where 0 db represents level of reference signal
Intermediate Frequency Bandwidths:	6, 30 and 150 cps
C.R.T.:	6-inch diameter with long-persistence phosphor

For further details, write: Marconi Instrumentation Dept:
6035 Cote de Liesse Road
Montreal 16, Quebec.

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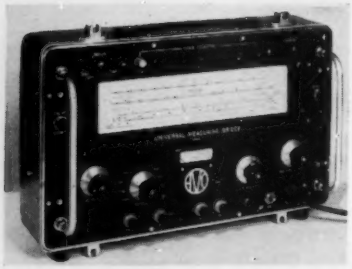
Universal measuring bridge is self-contained



A completely self-contained universal measuring bridge weighing 16 lb. and measuring 15 in. by 10 in. by 10 in. for operation on 110 volts, 60 cps has been announced by AVO.

The instrument has its own l-f 1,000 cps generator feeding the bridge circuit for inductance and capacity measurements, but resistance measurements are made by feeding d-c to the bridge network. Balance indication is shown on a panel meter that operates in conjunction with a VTVM circuit, and has a variable sensitivity control so that balance sensitivity can be varied to suit the degree of the out-of-balance condition of the bridge. These ranges are covered: Resistances: 0.1 ohm—1,000 megohms in 6 ranges. Capacity — 1 uufd-1,000 ufd in 6 ranges. Inductance 1mh-1,000 h in 6 ranges. In all cases, accuracy is claimed to be ± 2% at mid-scale. The unknown value is directly indicated on slide rule type scale, together with a suitable multiplier, and the total effective scale length for each type of measurement is approximately 50 inches.

R. H. Nichols Ltd., Toronto. (552)

Silicon power rectifiers

Hermetically sealed silicon rectifying cells for all types of power applications are now available from the Canadian Westinghouse Company. They can be used at high temperatures and are capable of operation at a junction temperature of 190 deg. C with no detectable change of characteristics due to aging. The rectifying case is the cathode terminal (metallic rectifier positive).

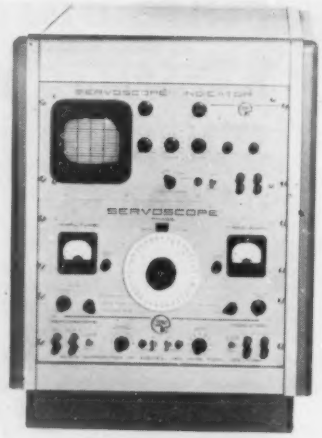
The exteriors are plated to maintain low contact resistance, with solid copper bases for rigidity and thermal mass. They weigh from 0.65 to 4.4 ounces and may be mounted in any position.

The rectifying cells are designated type WN-5051, WN-5091 and N-5082, each with different amperage and voltage rating. They are available from 80 to 350 amperes with ratings from 50 to 400 peak inverse volts. In addition to being available as individual units, the cells are offered in complete rectifier assemblies.

Canadian Westinghouse Co. Ltd. (553)

Full range servo analyzer

A new Model F Servoscope Servo Analyzer has been introduced by Servo Corporation of America. It was



developed to measure frequencies as high as 100.0 cps, yet still afford low end coverage at .005 cps. The Model F provides sine, modulated sine and square wave signals as well as the linear sweep on four ranges from .005 to 100 cps.

For less exacting requirements where this full range is not necessary, SCA offers four other models. All five models will accept carrier frequencies of 50 to 5,000 cycles from the same source used for the system under test.

Measurement Engineering Ltd., Arnprior, Ont. (554)

Variable composition resistor

Precision Electronic Components (1956) Ltd. are now producing a new ½ in. dia. variable composition resistor which will meet the MIL-R-94A specifications of style RV6.

This unit is completely enclosed and the shaft is sealed; it can safely be rated at 1/3 watt at 70°C ambient temperature, and derated at 120°C.

Precision Electronic Components (1956) Ltd., Toronto. (555)

Static charge voltmeter

A new type of static voltmeter that provides continuous measurements of static charges, is available from Dawe Instruments Ltd. Called the Type 635, the voltmeter gives both field and contact readings, over a range of 0.1 to 5,000 volts. It shows strength and location of the charges and rate of build up. It also measures current and insulation resistance, and indicates direct polarity.

Dawe Instruments Ltd., (Canadian Division). (556)

New VTVM kit

The growing range of electronic kits now has another member—the Starkit —Model VMK-1 vacuum tube voltmeter. The specifications are as follows:

Power Supply: 105 to 125 vac at 60 cps; Power Consumption: 20 watts at 115 volts; Ranges: dc volts, 1.5 to 1,200 in seven ranges; ac volts, 1.5 to 1,200 in seven ranges; Peak to Peak, 4 to 3,200 in seven ranges; Ohms, 0.2 ohms to 1,000 meg ohms in seven ranges; Frequency: ac measurement to approximately 2 megacycles; Meter: 350 microamps; Tubes: 12AU7—Balanced Bridge and 6AL5 — rectifier; Physical size: 8½ in. high, 6 in. wide, 3¾ in. deep.

Stark Electronic Instruments Ltd., Ajax, Ont. (557)

(Continued on page 57)

1,000,000,000

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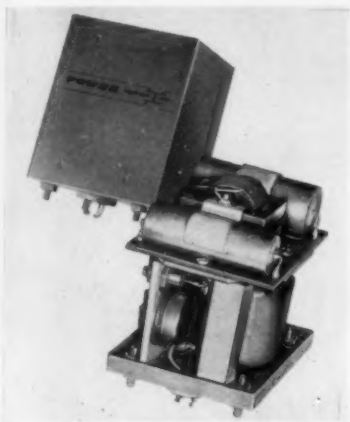
Converter units will stand shock treatment

Four new dc-dc converters utilizing semiconductors have been announced by Power Sources. Units are available with inputs of 12 and 28 volts d-c and filtered d-c outputs of 325 volts at 100 and 200 ma. These supplies are hermetically packaged in cans 3 1/16 x 3 3/16 x 2⅝ in. and are designed primarily for use where operating conditions require efficiency and reliability. The units can be operated in ambient temperatures from —55° to +75° C with efficiencies as high as 90% according to the manufacturer. The elimination of moving parts permits use of the converters under conditions of shock and vibration.



Regulation on the standard units is claimed to be 20% with 0.5% regulation, plus special input and output voltages and capacities up to 500 watts provided on a custom basis.

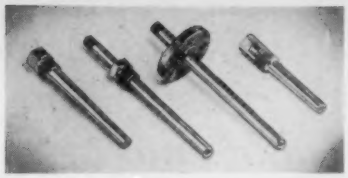
Power Sources Inc., Arlington, Mass. (558)

Thermowells protect thermocouples

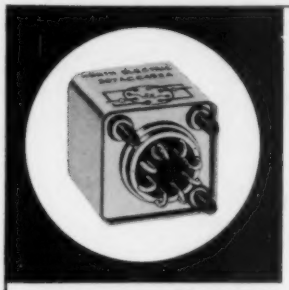
A new, expanded line of thermowells, both bar stock and built-up types, is now being offered by Thermo Electric (Canada) Ltd. These units provide a means of protecting thermocouples against mechanical injury and corrosive or contaminating atmospheres.

T-E Thermowells are available in over 5,700 different combinations to satisfy almost any temperature, environmental or installation requirements. Choice of a wide range of alloys provides individual thermowells to meet specific conditions of high temperature, oxidation or reduction, chemical corrosion, metallic amalgamation, mechanical shock or stress, and sudden temperature change.

Bar stock wells are drilled by the rifle boring process with bore concentricity guaranteed within 10% of wall thickness. They are available flanged, threaded—with hex head or wrench flats, or with ground joints. Built-up wells of seamless pipe are available with threaded mounting bushings or flanges. Each thermowell, both bar stock and built-up, is given an internal hydrostatic test as a final precaution against pressure failure.



Thermo Electric (Canada) Ltd., Brampton, Ont. (559)



Subminiature relay IR 207

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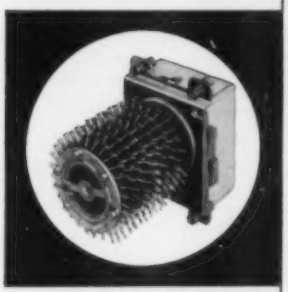

High precision rotary switch RVF

Some of the fields in which Ericsson and North relays and switches are now serving:

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Computing Machines
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Airline reservations network ("Reservisor")
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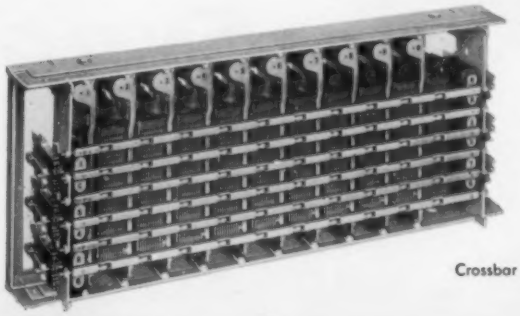
Hydro Power Supervisory Controls



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Heavy space bookings for Canadian IRE show

Demand for space at the Institute of Radio Engineers' Canadian convention-exposition, to be held in Toronto October 16-18, is extremely heavy, says Clare Norris, general chairman.

Britain's Board of Trade has earmarked a big section for British participation in this largest Canadian electronics exposition. Canada's own National Research Council and the Department of National Defence have booked space for the second time.

From overseas

Exhibits will include radio and television transmission equipment, radar, control mechanisms, computers, aeronautical and navigational aids, nuclear industry supplies and service and many other electronic devices.

In addition to the exhibitors already booked, further applications are expected to include more overseas participation.

Last year's exhibitors booked 262 booths and although this space has been stepped up to 309 booths, it may not be enough to meet exhibitors' needs.

Dr. George Sinclair, professor of electrical engineering at the University of Toronto, and chairman of the convention's technical paper program, is planning for the reading of 100 papers. One session, he says will be devoted to "Human Engineering," to treat primarily the designing of machinery (such as jet planes) where humans are a limiting factor in performance.

The IRE convention is offering a number of student travel awards to each of its student branches across Canada registered by October 11 this year, says chairman Norris.

Three scientists who are behind the new solid-state device

Men behind new solid-state device: H. Seidel, G. Feher, D. Scovil.

Spin oscillator should step up range of radio astronomy

Another new solid-state device, which will oscillate at microwave frequencies, has been developed by three scientists of the Bell Telephone Laboratories. The device, still in an early research stage, is expected to have very low noise compared with conventional microwave devices and it should therefore be possible to amplify signals several hundred times weaker than those usable at present.

The device, which might be called a spin oscillator, will also operate, in principle, as an amplifier. At a demonstration a crystal containing a small amount of paramagnetic salt, produced continuous oscillations at 9,000 megacycles with a power output of about 20 microwatts.

This was the first successful application to a solid-state device of the relatively new "master" — microwave amplification by stimulated emission of radiation — principle.

Among the possible uses for the device is in radio astronomy where it could extend the range considerably. It could also result in radically new long distance communication systems to carry television programs and telephone calls across the continent.

BIG EVENTS FOR YOUR DIARY

June

5-7 Canadian Manufacturers' Association, 86th Annual Meeting, Toronto.

12-14 Engineering Institute of Canada, Annual Meeting, Banff.

20-21 RETMA Annual Convention, Ste. Adele en Haut, Quebec.

24-28 AIEE Summer General Meeting, Montreal.

July

10-17 International Union of Crystallography, Fourth General Assembly and International Congress, McGill University.

August

20-23 Western Electronic Show & Convention, San Francisco.

September

3-14 International Union of Geodesy & Geophysics, Eleventh General Assembly, University of Toronto.

4-6 Special Technical Conference on Magnetic Amplifiers, Pittsburgh.

7-9 National Electronics Conference, Chicago.

October

9-11 CEMA Annual Convention, Niagara Falls, Ont.

16-18 IRE Canadian Convention & Exposition, Toronto.

Spotlight turns on IGY opening

July 1 is the opening date of the International Geophysical Year. Next month's issue of Electronics Engineering will turn the spotlight on Canada's contribution to IGY, with articles covering both the general field and the technical work that has been done on specialized equipment developed in Canada.

Dr. J. L. Yen and Dr. D. A. MacRae will contribute a paper on radio astronomy. In this they give a summary of the history of radio astronomy, the potentials of the new tool and a review of the technical work carried out on the University's radio telescopes.

Among many other feature articles will be one on "True Motion Marine Radar" in which technical features of the new Decca equipment will be described.

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